Measuring Water in IRRIGATION CHANNELS

FARMERS' BULLETIN NO. 1683

U. S. DEPARTMENT OF AGRICULTURE

THIS BULLETIN describes the Parshall measuring flume, the various common weirs, and their adaptability to the measurement of irrigation deliveries to farms.

Because of the growing need for accurate measurement of irrigation supplies, the Parshall measuring flume is now used extensively. This practical measuring device, as described in this bulletin, is made in sizes from 3 inches to 8 feet. Its capacity of flow ranges from less than 0.1 second-foot to more than 100 second-feet. Flumes up to 3 feet are used generally to measure the water delivered to farms, while sizes above that range are intended to measure flows in large laterals and ditches.

The Parshall flume is accurate within practical limits and can withstand relatively high degrees of submergence without affecting the indicated rate of flow. High velocities of discharge minimize sand and silt deposits, which would otherwise interfere with the accuracy of measurement, and the flume can be constructed of reinforced concrete, timber, or sheet metal. However, under certain conditions limiting grade of channel and capacity of flow, the Parshall flume is more difficult to install correctly for satisfactory operation than other devices commonly used.

Washington, D. C.

Issued January 1932
Revised October 1941

MEASURING WATER IN IRRIGATION CHANNELS [1]

By R. L. Parshall, *senior irrigation engineer, Division of Irrigation, Soil Conservation Service*

Contents

INTRODUCTION

The principal objectives of measuring irrigation supplies accurately in main canals, laterals, and deliveries to individual farmers are the equitable distribution of the water and its beneficial and economical use. This bulletin describes different practical water-measuring devices suitable for use in open irrigation channels, principally as adapted to relatively small flows in laterals and turn-out deliveries to individual water users.

WEIRS

The weir is the simplest of all the practical devices commonly used in the measurement of small water supplies, and when operated under standard controlled conditions the most accurate. In its simplest form, it consists in placing across the channel a bulkhead of timber or concrete having in its top edge a notched opening of fixed dimensions and shape through which a stream may flow. This opening is called the weir notch; its bottom edge is the crest; and the depth of water passing over the crest is the head (as measured at a definite point upstream from the weir bulkhead). The horizontal distances from the ends of the crest to the side walls of the weir box are called the end contractions, and the vertical distance from the crest to the floor of the weir box or the bed of the channel, is the bottom contraction. When these distances are great enough to cause water to pond above the weir, so that it approaches the weir notch at a low velocity, the weir is said to have complete contractions. To secure this condition, the banks or sides of the channel upstream from the bulkhead must be out from the ends of the crest at least twice the maximum depth of

[1] Prepared under the direction of W. W. McLaughlin, Chief, Division of Irrigation, Soil Conservation Service, and in cooperation with the Colorado Agricultural Experiment Station.

water over the weir; the bottom or bed of the channel must be lower than the crest by at least three times this maximum depth, and the velocity of approach must not exceed about 0.3 foot per second. These limiting contraction distances so define the dimensions of the channel that a high degree of accuracy of the discharge measurements may be realized. However, since this bulletin is intended to describe measuring devices for general field use, where merely reasonable degrees of accuracy are acceptable, these contraction distances have been modified to conform to common dimensions of the weir-box structure. No great sacrifice of accuracy in the measurements of flow results from this modification.

For proper operation of completely contracted weirs, the channel upstream from the bulkhead must be large enough to insure adequate stilling of the water. This stilling basin above the weir is called the weir pond. The sheet of water passing through the notch and falling over the weir crest is termed the nappe. When the water surface downstream from the bulkhead is far enough below the crest so that air has free access beneath the nappe, the flow is said to be free; otherwise it is submerged. Observations show that a head of 0.1 foot over such weirs is enough to permit the stream to clear the downstream edges of the crest and sides.

Three types of weirs operating with complete contractions are considered in this bulletin: (1) The rectangular weir, the weir notch of which has a level crest and vertical sides; (2) the Cipolletti, or trapezoidal, weir, having a level crest but having the sides of the notch inclined outward from the vertical at slopes of 1 unit horizontal to 4 units vertical; (3) the 90° triangular-notch weir, formed by side slopes 45° from the vertical, meeting in a point. This type has no crest length.

CONSTRUCTION AND SETTING

The crest and sides of these types of weirs should be straight and sharp-edged and usually one-eighth to one-quarter of an inch in thickness. The crest of the rectangular and the Cipolletti weirs should be level between the end points, and the sides should set at exactly the proper angle with the crest. The sides of the triangular-notch weir should make 45° angles with a vertical line through the point of intersection of the two sidepieces.

As a temporary expedient in making approximate measurements of small flows in earthen channels, a portable weir may be used. This may be made from a piece of stiff sheet metal cut in a semicircle approximately the shape of the cross section of the channel but somewhat larger, with a weir notch cut in the top edge. In setting this weir, it is only necessary to force the metal plate firmly into the soft bottom and sides of the channel, normal to the direction of flow, and then adjust the crest to a level position by tapping down the higher side.

If a more permanent structure is desired, a wooden bulkhead supported properly by end posts set well into the sides and bottom of the ditch may be built across the channel. The weir notch may then be cut into the top of the barrier, or the top pieces of planking may be made of such length and so fixed in place as to define the sides of the notch for a particular length of crest. Experience has indicated that where the notch is made with crest and sides of wood,

the edges may split, crack, or be crushed, causing irregularities and unsatisfactory measurements. Therefore it is the better practice to make the rectangular notch opening 3 inches longer than necessary, and use 1½- by 1½- by ⅛-inch angle-iron pieces cut to the proper length for the finished crest and sides, as shown in figure 1. The sidepieces for such a rectangular weir should first be set temporarily and the crest piece placed firmly between them. A carpenter's square and level should be used in finally determining the proper

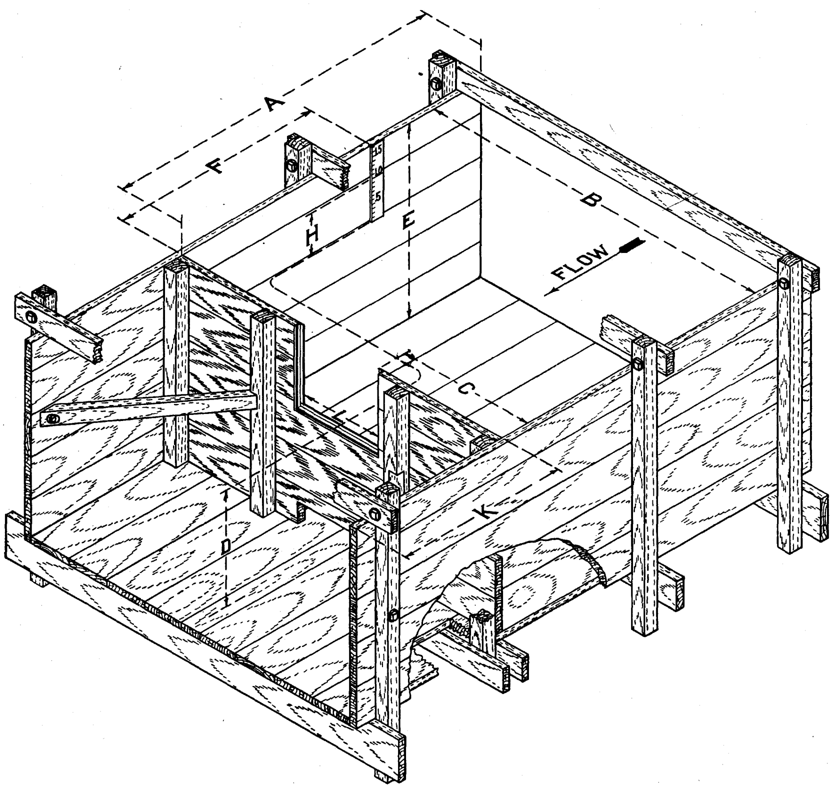


FIGURE 1.—Weir box with rectangular weir notch formed by angle-iron crest and sides. Letters have meanings as follows: A, length of box above weir notch; B, total width of box; C, distance from end of crest to side of box; D, distance from crest to bottom of box; E, total depth of box; F, gage distance; H, maximum head; K, length of box below weir notch; L, length of weir crest.

position of the vertical sidepieces. Heavy round-headed screws should be used to hold the pieces firmly in place.

It is somewhat more difficult to construct the Cipolletti type of weir, where angle irons are used for the crest and sides, because of the sloping sidepieces. For this reason, it is perhaps best to cut the notch to exact dimensions in a sheet of stiff metal and then fasten the sheet to the upstream face of the bulkhead, cutting the notch in the bulkhead 2 inches oversize in order not to interfere with the nappe. One objection to the Cipolletti type of weir, if only a bulkhead is constructed, is the difficulty of maintaining the proper side and bottom contraction

distances. To overcome this difficulty the weir bulkhead may be built inside a wooden or concrete structure such as that shown in figure 1. Dimensions of a structure suitable for these types of weirs are given in table 1. The letters at the heads of the columns in this table refer to the corresponding lettered dimensions in figure 1.

The weir-box structure should be set in a straight section of the channel, with the floor level in both directions and the side walls vertical. To prevent undermining or washing around the structure, cut-off walls should be provided at both ends and the back-fill well tamped in place. It is desirable to set the bulkhead upstream from the lower end in order to have a portion of the floor to serve as an apron in preventing erosion of the bottom of the channel. The banks and bottom of the channel for a distance of 15 to 20 feet upstream from the weir box should be trimmed to conform approximately to the cross section of the box.

TABLE 1.—*Weir-box dimensions for rectangular, Cipolletti, and 90° triangular-notch weirs*

[Letters refer to dimensions, fig. 1]

RECTANGULAR AND CIPOLLETTI WEIRS

Discharge (second-feet)	H Maximum head	L Length of weir crest	A Length of box above weir notch	K Length of box below weir notch	B Total width of box	E [1] Total depth of box	C Distance from end of crest to side of box	D Distance from crest to bottom of box	F Gage distance
	Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
¼ to 3	1.0	1	6	2	3	3	1	1½	4
2 to 5	1.1	1½	7	3	4	3	1¼	1½	4½
4 to 8	1.2	2	8	4	5	3½	1½	1¾	5
6 to 14	1.3	3	9	5	7	4	2	2	5½
10 to 22	1.5	4	10	6	9	4	2½	2	6
15 to 25	1.5	6	12	6	11½	4½	2¾	2½	6
20 to 50	1.5	8	16	8	14	4¾	3	2¾	8
25 to 60	1.5	10	20	8	17	5	3½	3	8
90° TRIANGULAR-NOTCH WEIR									
½ to 2½	1.00	--------	6	2	5	3	--------	1½	4
2 to 4⅓	1.25	--------	6½	3	6½	3¼	--------	1½	5

[1] This distance allows for about 6 inches freeboard above highest water level in weir box.

A main obstacle to accuracy in the use of weirs in the field is caused by sand and silt accumulating in the weir box. Cleaning by means of a hand shovel or by team and scraper where convenient, is frequently necessary to maintain proper contraction distances. For cleaning the weir box, an opening large enough for deposits to be sluiced through and passed downstream, can be provided in the bulkhead at the floor line beneath the weir notch (fig. 1). A removable gate or short piece of planking placed on the upstream side of the opening serves as a cover, which may be securely fixed in place when the weir is in operation.

MEASUREMENTS

The rate of flow in cubic feet per second (second-feet) over the weir crest is determined directly by the depth or head (H) in feet and the length of crest (L) in feet. As the water passes through the weir

notch, its surface curves downward. This curved surface, or draw-down, extends upstream a short distance from the plane of the weir notch and depends upon the depth of water over the crest. The true head (H) should therefore be determined at a point in the quiet water far enough upstream from the weir to be beyond the effect of this draw-down. In general practice, this distance to the gage point should not be less than four times the maximum head to be run over the crest. For lesser flows the same gage point should be used. Under ordinary conditions, this head may also be taken at the wall of the weir box at either end of the bulkhead. A staff gage, having a graduated scale on which the zero is at the same elevation as the weir crest, is usually attached to the inside face of the weir box in a vertical position at the gage point. For more accurate readings of the head, use may be made of a stilling well such as is described on page 28 and illustrated in figure 16.

Where a simple weir bulkhead is placed across the channel, a flat-top stake or post may be driven into the bed of the weir pond, at the proper distance back from the weir, until its top is at the same elevation as the crest of the weir. The depth of the water over this post will be the head on the crest. The post should be placed beyond the effect of the draw-down and close enough to the bank of the channel to be reached easily.

To determine the rate of discharge over the weir, observe the depth of water on the weir crest in feet or inches and then refer to table 2, 3, or 4, depending on the type of weir in use. These tables are for free-flow conditions and are applicable only to weirs installed and operated in the manner previously described. Submerged flow over weirs is generally unsatisfactory, and for this reason the subject is omitted from the discussion on weirs.

TABLE 2.—*Discharge table for rectangular weirs with complete contractions*

Head, H [1]		Discharge, Q, for crest lengths, L, of—							
		1 foot	1.5 feet	2 feet	3 feet	4 feet	6 feet	8 feet	10 feet
Ft.	*In.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*
0.10	1 3/16	0.11	0.16	0.22	0.33	0.44	0.62	0.84	1.05
.11	1 5/16	.12	.18	.25	.37	.50	.73	.97	1.21
.12	1 7/16	.14	.20	.28	.42	.57	.83	1.10	1.38
.13	1 9/16	.15	.22	.32	.47	.64	.93	1.24	1.56
.14	1 11/16	.17	.25	.35	.53	.71	1.04	1.39	1.74
.15	1 13/16	.19	.28	.39	.58	.79	1.15	1.54	1.93
.16	1 15/16	.21	.31	.43	.64	.86	1.27	1.70	2.12
.17	2 1/16	.23	.34	.47	.70	.95	1.39	1.86	2.33
.18	2 3/16	.25	.37	.51	.76	1.03	1.52	2.03	2.53
.19	2 1/4	.27	.40	.55	.83	1.11	1.64	2.20	2.75
.20	2 3/8	.29	.44	.59	.89	1.19	1.78	2.37	2.97
.21	2 1/2	.31	.47	.63	.95	1.28	1.91	2.55	3.19
.22	2 5/8	.34	.50	.68	1.02	1.37	2.05	2.73	3.42
.23	2 3/4	.36	.54	.72	1.09	1.46	2.19	2.92	3.66
.24	2 7/8	.38	.57	.77	1.16	1.55	2.33	3.11	3.90
.25	3	.40	.61	.82	1.23	1.65	2.48	3.31	4.14
.26	3 1/8	.43	.65	.86	1.31	1.75	2.63	3.51	4.39
.27	3 1/4	.45	.68	.91	1.38	1.85	2.78	3.71	4.65
.28	3 3/8	.48	.72	.96	1.46	1.95	2.93	3.92	4.91
.29	3 1/2	.50	.76	1.02	1.53	2.05	3.09	4.13	5.17

See footnote at end of table.

Table 2.—*Discharge table for rectangular weirs with complete contractions*—Con.

Head, H[1]		Discharge, Q, for crest lengths, L, of—							
		1 foot	1.5 feet	2 feet	3 feet	4 feet	6 feet	8 feet	10 feet
Ft.	*In.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*
0.30	3 5/8	0.53	0.80	1.07	1.61	2.16	3.25	4.34	5.44
.31	3 3/4	.55	.84	1.12	1.69	2.26	3.41	4.56	5.71
.32	3 13/16	.58	.88	1.18	1.77	2.37	3.58	4.78	5.99
.33	3 15/16	.61	.92	1.23	1.86	2.48	3.75	5.01	6.27
.34	4 1/16	.63	.96	1.28	1.94	2.60	3.92	5.24	6.56
.35	4 3/16	.66	1.00	1.34	2.02	2.71	4.09	5.47	6.85
.36	4 5/16	.69	1.04	1.40	2.11	2.82	4.26	5.70	7.14
.37	4 7/16	.72	1.08	1.45	2.20	2.94	4.44	5.94	7.44
.38	4 9/16	.74	1.13	1.51	2.28	3.06	4.62	6.18	7.74
.39	4 11/16	.77	1.17	1.57	2.37	3.18	4.80	6.43	8.05
.40	4 13/16	.80	1.21	1.63	2.46	3.30	4.99	6.67	8.36
.41	4 15/16	.83	1.26	1.69	2.55	3.42	5.17	6.92	8.67
.42	5 1/16	.86	1.30	1.75	2.65	3.54	5.36	7.18	8.99
.43	5 3/16	.89	1.35	1.81	2.74	3.67	5.55	7.43	9.31
.44	5 1/4	.92	1.40	1.88	2.83	3.80	5.75	7.69	9.63
.45	5 3/8	.96	1.44	1.94	2.93	3.93	5.94	7.95	9.96
.46	5 1/2	.99	1.49	2.00	3.03	4.05	6.14	8.22	10.3
.47	5 5/8	1.02	1.54	2.07	3.12	4.18	6.34	8.48	10.6
.48	5 3/4	1.05	1.59	2.13	3.22	4.32	6.54	8.75	11.0
.49	5 7/8	1.08	1.64	2.20	3.32	4.45	6.74	9.03	11.3
.50	6	1.11	1.68	2.26	3.42	4.58	6.95	9.30	11.7
.51	6 1/8	1.15	1.73	2.33	3.52	4.72	7.15	9.58	12.0
.52	6 1/4	1.18	1.78	2.40	3.62	4.86	7.36	9.86	12.4
.53	6 3/8	1.21	1.84	2.46	3.73	4.99	7.57	10.1	12.7
.54	6 1/2	1.25	1.89	2.53	3.83	5.13	7.79	10.4	13.1
.55	6 5/8	1.28	1.94	2.60	3.94	5.27	8.00	10.7	13.4
.56	6 3/4	1.31	1.99	2.67	4.04	5.42	8.22	11.0	13.8
.57	6 13/16	1.35	2.04	2.74	4.15	5.56	8.43	11.3	14.2
.58	6 15/16	1.38	2.09	2.81	4.26	5.70	8.65	11.6	14.5
.59	7 1/16	1.42	2.15	2.88	4.36	5.85	8.88	11.9	14.9
.60	7 3/16	1.45	2.20	2.96	4.47	6.00	9.10	12.2	15.3
.61	7 5/16	1.49	2.25	3.03	4.59	6.14	9.33	12.5	15.7
.62	7 7/16	1.52	2.31	3.10	4.69	6.29	9.55	12.8	16.1
.63	7 9/16	1.56	2.36	3.17	4.81	6.44	9.78	13.1	16.4
.64	7 11/16	1.60	2.42	3.25	4.92	6.59	10.0	13.4	16.8
.65	7 13/16	1.63	2.47	3.32	5.03	6.75	10.2	13.7	17.2
.66	7 15/16	1.67	2.53	3.40	5.15	6.90	10.5	14.0	17.6
.67	8 1/16	1.71	2.59	3.47	5.26	7.05	10.7	14.4	18.0
.68	8 3/16	1.74	2.64	3.56	5.38	7.21	10.9	14.7	18.4
.69	8 1/4	1.78	2.70	3.63	5.49	7.36	11.2	15.0	18.8
.70	8 3/8	1.82	2.76	3.71	5.61	7.52	11.4	15.3	19.2
.71	8 1/2	1.86	2.81	3.78	5.73	7.68	11.7	15.7	19.6
.72	8 5/8	1.90	2.87	3.86	5.85	7.84	11.9	16.0	20.1
.73	8 3/4	1.93	2.93	3.94	5.97	8.00	12.2	16.3	20.5
.74	8 7/8	1.97	2.99	4.02	6.09	8.17	12.4	16.6	20.9
.75	9	2.01	3.05	4.10	6.21	8.33	12.7	17.0	21.3
.76	9 1/8	2.05	3.11	4.18	6.33	8.49	12.9	17.3	21.7
.77	9 1/4	2.09	3.17	4.26	6.45	8.66	13.2	17.7	22.2
.78	9 3/8	2.13	3.23	4.34	6.58	8.82	13.4	18.0	22.6
.79	9 1/2	2.17	3.29	4.42	6.70	8.99	13.7	18.3	23.0
.80	9 5/8	2.21	3.35	4.51	6.83	9.16	13.9	18.7	23.4
.81	9 3/4	2.25	3.41	4.59	6.95	9.33	14.2	19.0	23.9
.82	9 13/16	2.29	3.47	4.67	7.08	9.50	14.4	19.4	24.3
.83	9 15/16	2.33	3.54	4.75	7.21	9.67	14.7	19.7	24.8
.84	10 1/16	2.37	3.60	4.84	7.33	9.84	15.0	20.1	25.2
.85	10 3/16	2.41	3.66	4.92	7.46	10.0	15.2	20.4	25.7
.86	10 5/16	2.46	3.72	5.01	7.59	10.2	15.5	20.8	26.1
.87	10 7/16	2.50	3.79	5.10	7.72	10.4	15.7	21.1	26.6
.88	10 9/16	2.54	3.85	5.18	7.85	10.5	16.0	21.5	27.0
.89	10 11/16	2.58	3.92	5.27	7.99	10.7	16.3	21.9	27.5
.90	10 13/16	2.62	3.98	5.35	8.12	10.9	16.5	22.2	27.9
.91	10 15/16	2.67	4.05	5.44	8.25	11.1	16.8	22.6	28.4
.92	11 1/16	2.71	4.11	5.53	8.38	11.2	17.1	23.0	28.8
.93	11 3/16	2.75	4.18	5.62	8.52	11.4	17.4	23.3	29.3
.94	11 1/4	2.79	4.24	5.71	8.65	11.6	17.6	23.7	29.8
.95	11 3/8	2.84	4.31	5.80	8.79	11.8	17.9	24.1	30.2
.96	11 1/2	2.88	4.37	5.89	8.93	12.0	18.2	24.5	30.7
.97	11 5/8	2.93	4.44	5.98	9.06	12.2	18.5	24.8	31.2
.98	11 3/4	2.97	4.51	6.07	9.20	12.3	18.8	25.2	31.7
.99	11 7/8	3.01	4.57	6.15	9.34	12.5	19.0	25.6	32.2

See footnote at end of table.

TABLE 2.—*Discharge table for rectangular weirs with complete contractions*—Con.

Head, H[1]		Discharge, Q, for crest lengths, L, of—							
		1 foot	1.5 feet	2 feet	3 feet	4 feet	6 feet	8 feet	10 feet
Ft.	*In.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*
1.00	12	3.06	4.64	6.25	9.48	12.7	19.3	26.0	32.6
1.01	12⅛	----------	4.71	6.34	9.62	12.9	19.6	26.4	33.1
1.02	12¼	----------	4.78	6.43	9.76	13.1	19.9	26.7	33.6
1.03	12⅜	----------	4.85	6.52	9.90	13.3	20.2	27.1	34.1
1.04	12½	----------	4.92	6.62	10.0	13.5	20.5	27.5	34.6
1.05	12⅝	----------	4.98	6.71	10.2	13.7	20.7	27.9	35.1
1.06	12¾	----------	5.05	6.80	10.3	13.8	21.0	28.3	35.6
1.07	12 13/16	----------	5.12	6.90	10.5	14.0	21.3	28.7	36.1
1.08	12 15/16	----------	5.20	6.99	10.6	14.2	21.6	29.1	36.6
1.09	13 1/16	----------	5.26	7.09	10.8	14.4	21.9	29.5	37.1
1.10	13 3/16	----------	5.34	7.19	10.9	14.6	22.2	29.9	37.6
1.11	13 5/16	----------	5.41	7.28	11.0	14.8	22.5	30.3	38.1
1.12	13 7/16	----------	5.48	7.38	11.2	15.0	22.8	30.7	38.6
1.13	13 9/16	----------	5.55	7.47	11.3	15.2	23.1	31.1	39.1
1.14	13 11/16	----------	5.62	7.57	11.5	15.4	23.4	31.5	39.6
1.15	13 13/16	----------	5.69	7.66	11.6	15.6	23.7	31.9	40.1
1.16	13 15/16	----------	5.77	7.76	11.8	15.8	24.0	32.3	40.6
1.17	14 1/16	----------	5.84	7.86	11.9	16.0	24.3	32.7	41.2
1.18	14 3/16	----------	5.91	7.96	12.1	16.2	24.6	33.1	41.7
1.19	14¼	----------	5.98	8.06	12.2	16.4	24.9	33.6	42.2
1.20	14⅜	----------	6.06	8.16	12.4	16.6	25.2	34.0	42.7
1.21	14½	----------	6.13	8.26	12.5	16.8	25.5	34.4	43.2
1.22	14⅝	----------	6.20	8.35	12.7	17.0	25.8	34.8	43.8
1.23	14¾	----------	6.28	8.46	12.8	17.2	26.2	35.2	44.3
1.24	14⅞	----------	6.35	8.56	13.0	17.4	26.5	35.6	44.8
1.25	15	----------	6.43	8.66	13.1	17.6	26.8	36.1	45.4
1.26	15⅛	----------	----------	----------	13.3	17.9	27.1	36.5	45.9
1.27	15¼	----------	----------	----------	13.4	18.1	27.4	36.9	46.4
1.28	15⅜	----------	----------	----------	13.6	18.3	27.7	37.3	47.0
1.29	15½	----------	----------	----------	13.8	18.5	28.0	37.8	47.5
1.30	15⅝	----------	----------	----------	13.9	18.7	28.3	38.2	48.1
1.31	15¾	----------	----------	----------	14.1	18.9	28.7	38.6	48.6
1.32	15 13/16	----------	----------	----------	14.2	19.1	29.0	39.1	49.2
1.33	15 15/16	----------	----------	----------	14.4	19.3	29.3	39.5	49.7
1.34	16 1/16	----------	----------	----------	14.6	19.6	29.6	39.9	50.3
1.35	16 3/16	----------	----------	----------	14.7	19.8	30.0	40.4	50.8
1.36	16 5/16	----------	----------	----------	14.9	20.0	30.3	40.8	51.4
1.37	16 7/16	----------	----------	----------	15.0	20.2	30.6	41.3	51.9
1.38	16 9/16	----------	----------	----------	15.2	20.4	30.9	41.7	52.5
1.39	16 11/16	----------	----------	----------	15.4	20.6	31.3	42.1	53.1
1.40	16 13/16	----------	----------	----------	15.5	20.9	31.6	42.6	53.6
1.41	16 15/16	----------	----------	----------	15.7	21.1	31.9	43.0	54.2
1.42	17 1/16	----------	----------	----------	15.9	21.3	32.2	43.5	54.7
1.43	17 3/16	----------	----------	----------	16.0	21.5	32.6	43.9	55.3
1.44	17¼	----------	----------	----------	16.2	21.7	32.9	44.4	55.9
1.45	17⅜	----------	----------	----------	16.3	22.0	33.2	44.8	56.5
1.46	17½	----------	----------	----------	16.5	22.2	33.6	45.3	57.0
1.47	17⅝	----------	----------	----------	16.7	22.4	33.9	45.7	57.6
1.48	17¾	----------	----------	----------	16.9	22.6	34.2	46.2	58.2
1.49	17⅞	----------	----------	----------	17.0	22.9	34.6	46.6	58.8
1.50	18	----------	----------	----------	17.2	23.1	34.9	47.1	59.3

[1] Values of discharge for heads up to 0.20 foot (crest lengths 1, 1½, 2, 3, and 4 feet) do not follow the formula, but are taken directly from the calibration curve. The discharge for heads 0.10 to 1.5 feet for the 6-, 8-, and 10-foot weirs are as computed by the formula $Q=3.33\ (L-0.2H)\ H^{3/2}$.

TABLE 3.—*Discharge table for Cipolletti weirs with complete contractions*

Head, H[1]		Discharge, Q, for crest lengths, L, of—							
		1 foot	1.5 feet	2 feet	3 feet	4 feet	6 feet	8 feet	10 feet
Ft.	*In.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*
0.10	1 3/16	0.11	0.16	0.23	0.33	0.44	0.64	0.85	1.06
.11	1 5/16	.12	.18	.26	.38	.50	.74	.98	1.23
.12	1 7/16	.14	.21	.29	.43	.57	.84	1.12	1.40
.13	1 9/16	.16	.24	.32	.48	.64	.95	1.26	1.58
.14	1 11/16	.17	.26	.36	.54	.71	1.06	1.41	1.73
.15	1 13/16	.19	.29	.39	.59	.79	1.17	1.56	1.96
.16	1 15/16	.21	.32	.43	.65	.87	1.29	1.72	2.15
.17	2 1/16	.23	.36	.47	.71	.96	1.41	1.89	2.36
.18	2 3/16	.25	.39	.51	.77	1.04	1.54	2.06	2.57
.19	2 1/4	.28	.42	.56	.83	1.12	1.67	2.23	2.79
.20	2 3/8	.30	.45	.60	.90	1.20	1.81	2.41	3.01
.21	2 1/2	.32	.48	.64	.97	1.29	1.94	2.59	3.24
.22	2 5/8	.35	.52	.69	1.04	1.38	2.08	2.78	3.47
.23	2 3/4	.37	.55	.74	1.11	1.47	2.23	2.97	3.71
.24	2 7/8	.39	.59	.79	1.18	1.57	2.38	3.17	3.96
.25	3	.42	.63	.84	1.25	1.67	2.53	3.37	4.21
.26	3 1/8	.45	.67	.89	1.33	1.77	2.68	3.57	4.46
.27	3 1/4	.47	.70	.94	1.40	1.87	2.83	3.78	4.72
.28	3 3/8	.50	.74	.99	1.48	1.97	2.99	3.99	4.99
.29	3 1/2	.53	.79	1.04	1.56	2.08	3.15	4.21	5.26
.30	3 5/8	.56	.83	1.10	1.64	2.19	3.32	4.43	5.53
.31	3 3/4	.59	.87	1.15	1.73	2.30	3.49	4.65	5.81
.32	3 13/16	.61	.91	1.21	1.80	2.41	3.66	4.88	6.09
.33	3 15/16	.64	.95	1.27	1.89	2.52	3.83	5.11	6.38
.34	4 1/16	.67	1.00	1.32	1.98	2.64	4.00	5.34	6.67
.35	4 3/16	.70	1.04	1.38	2.07	2.75	4.18	5.58	6.97
.36	4 5/16	.73	1.09	1.44	2.16	2.87	4.36	5.82	7.27
.37	4 7/16	.77	1.13	1.50	2.25	2.99	4.55	6.06	7.58
.38	4 9/16	.80	1.18	1.57	2.34	3.11	4.73	6.31	7.89
.39	4 11/16	.83	1.23	1.63	2.43	3.24	4.92	6.56	8.20
.40	4 13/16	.87	1.28	1.69	2.53	3.36	5.11	6.81	8.52
.41	4 15/16	.90	1.32	1.76	2.62	3.49	5.30	7.07	8.84
.42	5 1/16	.93	1.37	1.82	2.72	3.61	5.50	7.33	9.16
.43	5 3/16	.97	1.42	1.89	2.81	3.74	5.70	7.59	9.49
.44	5 1/4	1.00	1.47	1.95	2.91	3.87	5.90	7.86	9.83
.45	5 3/8	1.04	1.53	2.02	3.01	4.01	6.10	8.13	10.2
.46	5 1/2	1.07	1.58	2.09	3.11	4.14	6.30	8.40	10.5
.47	5 5/8	1.11	1.63	2.16	3.21	4.28	6.51	8.68	10.8
.48	5 3/4	1.15	1.68	2.23	3.32	4.41	6.72	8.96	11.2
.49	5 7/8	1.18	1.74	2.30	3.42	4.55	6.93	9.24	11.5
.50	6	1.22	1.79	2.37	3.53	4.69	7.14	9.52	11.9
.51	6 1/8	1.26	1.85	2.44	3.64	4.83	7.36	9.81	12.3
.52	6 1/4	1.30	1.90	2.51	3.74	4.97	7.57	10.1	12.6
.53	6 3/8	1.34	1.96	2.59	3.85	5.12	7.79	10.4	13.0
.54	6 1/2	1.38	2.02	2.66	3.96	5.26	8.02	10.7	13.4
.55	6 5/8	1.42	2.07	2.74	4.07	5.41	8.24	11.0	13.7
.56	6 3/4	1.46	2.13	2.81	4.18	5.56	8.47	11.3	14.1
.57	6 13/16	1.50	2.19	2.89	4.30	5.71	8.69	11.6	14.5
.58	6 15/16	1.54	2.25	2.97	4.41	5.86	8.92	11.9	14.9
.59	7 1/16	1.58	2.31	3.05	4.53	6.01	9.15	12.2	15.3
.60	7 3/16	1.62	2.37	3.13	4.64	6.17	9.39	12.5	15.6
.61	7 5/16	1.67	2.43	3.20	4.76	6.32	9.62	12.8	16.0
.62	7 7/16	1.71	2.49	3.28	4.88	6.47	9.86	13.1	16.4
.63	7 9/16	1.75	2.55	3.37	5.00	6.63	10.1	13.5	16.8
.64	7 11/16	1.80	2.62	3.45	5.12	6.79	10.3	13.8	17.2
.65	7 13/16	1.84	2.68	3.53	5.24	6.95	10.6	14.1	17.6
.66	7 15/16	1.89	2.75	3.61	5.36	7.11	10.8	14.4	18.1
.67	8 1/16	1.93	2.81	3.70	5.48	7.28	11.1	14.8	18.5
.68	8 3/16	1.98	2.87	3.79	5.61	7.44	11.3	15.1	18.9
.69	8 1/4	2.02	2.94	3.87	5.73	7.61	11.6	15.4	19.3
.70	8 3/8	2.07	3.01	3.95	5.86	7.77	11.8	15.8	19.7
.71	8 1/2	2.12	3.07	4.04	5.99	7.94	12.1	16.1	20.1
.72	8 5/8	2.16	3.14	4.13	6.12	8.11	12.3	16.5	20.6
.73	8 3/4	2.21	3.21	4.22	6.24	8.28	12.6	16.8	21.0
.74	8 7/8	2.26	3.28	4.31	6.38	8.45	12.9	17.1	21.4
.75	9	2.31	3.35	4.40	6.51	8.62	13.1	17.5	21.9
.76	9 1/8	2.36	3.42	4.49	6.64	8.80	13.4	17.8	22.3
.77	9 1/4	2.41	3.49	4.58	6.77	8.97	13.6	18.2	22.7
.78	9 3/8	2.46	3.56	4.67	6.90	9.15	13.9	18.6	23.2
.79	9 1/2	2.51	3.63	4.76	7.04	9.33	14.2	18.9	23.6

See footnote at end of table.

TABLE 3.—*Discharge table for Cipolletti weirs with complete contractions*—Con.

Head, H[1]		Discharge, Q, for crest lengths, L, of—							
		1 foot	1.5 feet	2 feet	3 feet	4 feet	6 feet	8 feet	10 feet
Ft.	*In.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*
0.80	9 5/8	2.56	3.70	4.85	7.18	9.51	14.5	19.3	24.1
.81	9 3/4	2.61	3.77	4.95	7.31	9.69	14.7	19.6	24.5
.82	9 13/16	2.66	3.84	5.04	7.45	9.87	15.0	20.0	25.0
.83	9 15/16	2.71	3.92	5.14	7.59	10.0	15.3	20.4	25.5
.84	10 1/16	2.77	3.99	5.23	7.73	10.2	15.6	20.7	25.9
.85	10 3/16	2.82	4.07	5.33	7.87	10.4	15.8	21.1	26.4
.86	10 5/16	2.87	4.14	5.43	8.01	10.6	16.1	21.5	26.9
.87	10 7/16	2.93	4.22	5.52	8.15	10.8	16.4	21.9	27.3
.88	10 9/16	2.98	4.29	5.62	8.30	11.0	16.7	22.2	27.8
.89	10 11/16	3.04	4.37	5.72	8.44	11.2	17.0	22.6	28.3
.90	10 13/16	3.09	4.45	5.82	8.59	11.4	17.2	23.0	28.7
.91	10 15/16	3.15	4.53	5.92	8.73	11.6	17.5	23.4	29.2
.92	11 1/16	3.20	4.60	6.02	8.88	11.7	17.8	23.8	29.7
.93	11 3/16	3.26	4.68	6.13	9.03	11.9	18.1	24.2	30.2
.94	11 1/4	3.32	4.76	6.23	9.17	12.1	18.4	24.5	30.7
.95	11 3/8	3.37	4.84	6.33	9.32	12.3	18.7	24.9	31.2
.96	11 1/2	3.43	4.92	6.44	9.48	12.5	19.0	25.3	31.7
.97	11 5/8	3.49	5.00	6.55	9.62	12.7	19.3	25.7	32.2
.98	11 3/4	3.55	5.09	6.64	9.78	12.9	19.6	26.1	32.7
.99	11 7/8	3.61	5.17	6.75	9.93	13.1	19.9	26.5	33.2
1.00	12	3.67	5.25	6.86	10.1	13.3	20.2	26.9	33.7
1.01	12 1/8	----------	5.33	6.96	10.2	13.5	20.5	27.3	34.2
1.02	12 1/4	----------	5.42	7.07	10.4	13.7	20.8	27.7	34.7
1.03	12 3/8	----------	5.50	7.18	10.6	13.9	21.1	28.2	35.2
1.04	12 1/2	----------	5.59	7.29	10.7	14.2	21.4	28.6	35.7
1.05	12 5/8	----------	5.67	7.40	10.9	14.4	21.7	29.0	36.2
1.06	12 3/4	----------	5.76	7.51	11.0	14.6	22.0	29.4	36.7
1.07	12 13/16	----------	5.84	7.62	11.2	14.8	22.4	29.8	37.3
1.08	12 15/16	----------	5.93	7.73	11.4	15.0	22.7	30.2	37.8
1.09	13 1/16	----------	6.02	7.84	11.5	15.2	23.0	30.6	38.3
1.10	13 3/16	----------	6.11	7.96	11.7	15.4	23.3	31.1	38.8
1.11	13 5/16	----------	6.20	8.07	11.8	15.6	23.6	31.5	39.4
1.12	13 7/16	----------	6.29	8.18	12.0	15.8	23.9	31.9	39.9
1.13	13 9/16	----------	6.38	8.29	12.2	16.0	24.3	32.4	40.4
1.14	13 11/16	----------	6.47	8.41	12.3	16.3	24.6	32.8	41.0
1.15	13 13/16	----------	6.56	8.53	12.5	16.5	24.9	33.2	41.5
1.16	13 15/16	----------	6.65	8.65	12.7	16.7	25.2	33.6	42.1
1.17	14 1/16	----------	6.74	8.76	12.8	16.9	25.6	34.1	42.6
1.18	14 3/16	----------	6.83	8.88	13.0	17.2	25.9	34.5	43.2
1.19	14 1/4	----------	6.93	9.00	13.2	17.4	26.2	35.0	43.7
1.20	14 3/8	----------	7.02	9.12	13.4	17.6	26.6	35.4	44.3
1.21	14 1/2	----------	7.11	9.24	13.5	17.8	26.9	35.8	44.8
1.22	14 5/8	----------	7.20	9.36	13.7	18.0	27.2	36.3	45.4
1.23	14 3/4	----------	7.30	9.48	13.9	18.3	27.6	36.7	45.9
1.24	14 7/8	----------	7.40	9.60	14.0	18.5	27.9	37.2	46.5
1.25	15	----------	7.49	9.72	14.2	18.7	28.2	37.6	47.1
1.26	15 1/8	----------	----------	----------	14.4	19.0	28.6	38.1	47.6
1.27	15 1/4	----------	----------	----------	14.6	19.2	28.9	38.5	48.2
1.28	15 3/8	----------	----------	----------	14.7	19.4	29.3	39.0	48.8
1.29	15 1/2	----------	----------	----------	14.9	19.6	29.6	39.5	49.3
1.30	15 5/8	----------	----------	----------	15.1	19.9	29.9	39.9	49.9
1.31	15 3/4	----------	----------	----------	15.3	20.1	30.3	40.4	50.5
1.32	15 13/16	----------	----------	----------	15.5	20.3	30.6	40.8	51.1
1.33	15 15/16	----------	----------	----------	15.6	20.6	31.0	41.3	51.6
1.34	16 1/16	----------	----------	----------	15.8	20.8	31.3	41.8	52.2
1.35	16 3/16	----------	----------	----------	16.0	21.1	31.7	42.2	52.8
1.36	16 5/16	----------	----------	----------	16.2	21.3	32.0	42.7	53.4
1.37	16 7/16	----------	----------	----------	16.4	21.5	32.4	43.2	54.0
1.38	16 9/16	----------	----------	----------	16.6	21.8	32.7	43.7	54.6
1.39	16 11/16	----------	----------	----------	16.8	22.0	33.1	44.1	55.2
1.40	16 13/16	----------	----------	----------	16.9	22.3	33.5	44.6	55.8
1.41	16 15/16	----------	----------	----------	17.1	22.5	33.8	45.1	56.4
1.42	17 1/16	----------	----------	----------	17.3	22.8	34.2	45.6	57.0
1.43	17 3/16	----------	----------	----------	17.5	23.0	34.6	46.1	57.6
1.44	17 1/4	----------	----------	----------	17.7	23.3	34.9	46.5	58.2
1.45	17 3/8	----------	----------	----------	17.9	23.5	35.3	47.0	58.8
1.46	17 1/2	----------	----------	----------	18.1	23.8	35.6	47.5	59.4
1.47	17 5/8	----------	----------	----------	18.3	24.0	36.0	48.0	60.0
1.48	17 3/4	----------	----------	----------	18.5	24.3	36.4	48.5	60.6
1.49	17 7/8	----------	----------	----------	18.7	24.5	36.7	49.0	61.2
1.50	18	----------	----------	----------	18.9	24.8	37.1	49.5	61.8

[1] Values of discharge for heads up to 0.20 foot (crest lengths 1, 1½, 2, 3, and 4 feet) do not follow the formula but are taken directly from the calibration curve. The discharge for heads 0.10 to 1.5 feet for the 6-, 8-, and 10-foot weirs are as computed by the formula $Q=3.367LH^{3/2}$.

TABLE 4.—*Discharge table for 90° triangular-notch weir with complete contractions*

Head, H		Discharge, Q	Head, H		Discharge, Q	Head, H		Discharge, Q
Ft.	*In.*	*Sec.-ft.*	*Ft.*	*In.*	*Sec.-ft.*	*Ft.*	*In.*	*Sec.-ft.*
0.20	2 3/8	0.046	0.55	6 5/8	0.564	0.90	10 13/16	1.92
.21	2 1/2	.052	.56	6 3/4	.590	.91	10 15/16	1.97
.22	2 5/8	.058	.57	6 13/16	.617	.92	11 1/16	2.02
.23	2 3/4	.065	.58	6 15/16	.644	.93	11 3/16	2.08
.24	2 7/8	.072	.59	7 1/16	.672	.94	11 1/4	2.13
.25	3	.080	.60	7 3/16	.700	.95	11 3/8	2.19
.26	3 1/8	.088	.61	7 5/16	.730	.96	11 1/2	2.25
.27	3 1/4	.096	.62	7 7/16	.760	.97	11 5/8	2.31
.28	3 3/8	.106	.63	7 9/16	.790	.98	11 3/4	2.37
.29	3 1/2	.115	.64	7 11/16	.822	.99	11 7/8	2.43
.30	3 5/8	.125	.65	7 13/16	.854	1.00	12	2.49
.31	3 3/4	.136	.66	7 15/16	.887	1.01	12 1/8	2.55
.32	3 13/16	.147	.67	8 1/16	.921	1.02	12 1/4	2.61
.33	3 15/16	.159	.68	8 3/16	.955	1.03	12 3/8	2.68
.34	4 1/16	.171	.69	8 1/4	.991	1.04	12 1/2	2.74
.35	4 3/16	.184	.70	8 3/8	1.03	1.05	12 5/8	2.81
.36	4 5/16	.197	.71	8 1/2	1.06	1.06	12 3/4	2.87
.37	4 7/16	.211	.72	8 5/8	1.10	1.07	12 13/16	2.94
.38	4 9/16	.225	.73	8 3/4	1.14	1.08	12 15/16	3.01
.39	4 11/16	.240	.74	8 7/8	1.18	1.09	13 1/16	3.08
.40	4 13/16	.256	.75	9	1.22	1.10	13 3/16	3.15
.41	4 15/16	.272	.76	9 1/8	1.26	1.11	13 5/16	3.22
.42	5 1/16	.289	.77	9 1/4	1.30	1.12	13 7/16	3.30
.43	5 3/16	.306	.78	9 3/8	1.34	1.13	13 9/16	3.37
.44	5 1/4	.324	.79	9 1/2	1.39	1.14	13 11/16	3.44
.45	5 3/8	.343	.80	9 5/8	1.43	1.15	13 13/16	3.52
.46	5 1/2	.362	.81	9 3/4	1.48	1.16	13 15/16	3.59
.47	5 5/8	.382	.82	9 13/16	1.52	1.17	14 1/16	3.67
.48	5 3/4	.403	.83	9 15/16	1.57	1.18	14 3/16	3.75
.49	5 7/8	.424	.84	10 1/16	1.61	1.19	14 1/4	3.83
.50	6	.445	.85	10 3/16	1.66	1.20	14 3/8	3.91
.51	6 1/8	.468	.86	10 5/16	1.71	1.21	14 1/2	3.99
.52	6 1/4	.491	.87	10 7/16	1.76	1.22	14 5/8	4.07
.53	6 3/8	.515	.88	10 9/16	1.81	1.23	14 3/4	4.16
.54	6 1/2	.539	.89	10 11/16	1.86	1.24	14 7/8	4.24
						1.25	15	4.33

LIMITATIONS OF WEIRS

The weir, when properly set and maintained, is considered one of the most accurate means of measuring flowing water, but when operated under field conditions such as are found in irrigation practice, it may be considerably in error owing to neglected maintenance and other causes. In order that a weir may continue to measure water accurately, the side and bottom contraction distances and the proper velocity of approach conditions must be maintained. Water flowing in earth channels usually carries sand and sediment which accumulate in the weir box or pond upstream from the weir bulkhead. This filling eventually destroys the standard bottom contraction distance and causes the weir to overregister because of the increased velocity of approach. The error thus caused in the rate of discharge is slight at first, but when the surface of the deposit is raised to the elevation of the crest, the increase in discharge over that indicated by the head is an appreciable amount.

Where accurate measurements of the flow are required, wooden crest and sides for the weir notch are not recommended, because natural wear and deterioration soon dull the edges of the notch and result in overregistration of the indicated discharge. A weir box built to provide proper contraction distances and extra length of floor to serve as an apron for preventing scour, requires a large amount of material as compared with that needed for a simple bulkhead structure.

In many cases the weir cannot be used as a free-flow measuring device because of the flat grade of the channel. The accompanying weir-discharge tables are useful only if the loss of head at the weir is not less than the measured depth of the water over the crest plus an additional 0.1 foot for the aeration of the nappe. If the surface of the water downstream from the weir rises above the crest level the flow is submerged, and the actual discharge is less than that indicated in the table for that particular head (H). The filling of deposit in the weir pond, rounded edges of the crest and sides, bulkhead inclined downstream, wooden notch with bevel on upstream side of bulkhead, downstream water surface at or slightly above the crest, nappe confined to prevent aeration, all tend to increase the rate of flow over the notch. High downstream water surface resists the flow through the notch and reduces the discharge.

Extended discussion of weirs without end contractions is not within the scope of this bulletin. For this type of weir two common settings have been used: First, where the end contractions are reduced to zero by having the width of the approach channel equal to that of the crest length and the width of the channel downstream great enough to permit complete aeration of the nappe; second, where the side walls of the structure are parallel and the weir bulkhead is placed well back from the lower end of the structure. For this combination the nappe must be aerated by suitable air vents. The standard weir with complete contractions is most generally used.

THE PARSHALL MEASURING FLUME

The Parshall measuring flume is a newly developed device intended primarily for use in connection with irrigation practice where the smaller sizes are especially suited to the requirements of measuring farm deliveries. This device consists of a converging section, a throat, and a diverging section, with the floor of the converging, or upstream section, level both longitudinally and transversely. The floor of the throat is inclined downward at a slope of 9 inches vertical to 24 inches horizontal, and the floor of the diverging or downstream section inclines upward at a slope of 6 inches vertical to 36 inches horizontal for throat widths of 1 to 8 feet. For this range of sizes the elevation of the floor at the downstream end of the flume is 3 inches lower than the crest, which is the line where the floor of the converging section joins the inclined floor of the throat section. The size of flume (W) is taken as the horizontal distance between the vertical parallel walls of the throat and is identical with the length of the crest. For the range of sizes 1 to 8 feet, the length of throat is 2 feet and the length of the converging section 3 feet. For the smaller flumes—3-, 6-, and 9-inch—the ratios of dimensions depart somewhat from those applicable to the larger flumes. The slope of the throat floor, however, is the same for all sizes. Table 5 gives the appropriate dimensions of the several throat widths, the lettered columns referring to the dimensions similarly identified in figure 2.

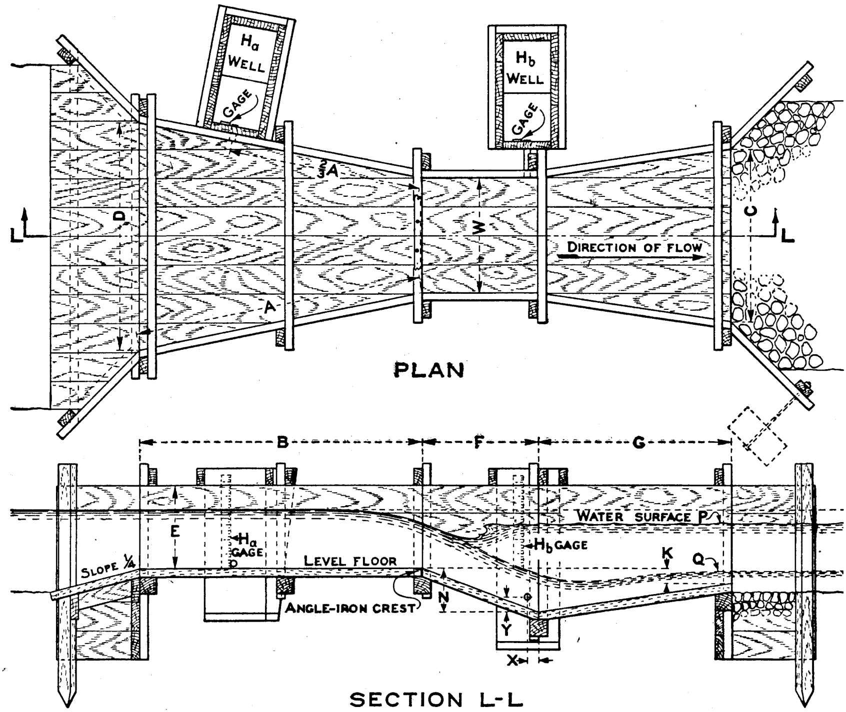


FIGURE 2.—Plan and elevation of the Parshall measuring flume showing dimensions of W, size of flume, in inches or feet; A, length of side wall of converging section; 2/3 A, distance back from end of crest to gage point; B, axial length of converging section; C, width of downstream end of flume; D, width of upstream end of flume; E, depth of flume; F, length of throat; G, length of converging section; K, difference in elevation between lower end of flume and crest; N, depth of depression in throat below crest; X, horizontal distance to H_b gage point upstream from lower edge of throat; Y, vertical distance to H_b gage point from low point in throat. See table 5 for actual dimensions for various sizes of flume.

TABLE 5.—*Dimensions and capacities of the Parshall measuring flume, for various throat widths, W*

[Letters refer to dimensions, fig. 2]

W		A		⅔A		B		C		D		E		F	G	K	N	X	Y	Free-flow capacity	
																				Maximum	Minimum
Ft.	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*In.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	*In.*	*Sec.-ft.*	*Sec.-ft.*
----	3	1	6⅜	1	¼	1	6	0	7	0	10³⁄₁₆	1	4	½	1	1	2¼	1	1½	1.1	0.03
----	6	2	⁷⁄₁₆	1	4⁵⁄₁₆	2	0	1	3⅝	1	3⅝	2	0	1	2	3	4½	2	3	3.9	.05
----	9	2	10⅝	1	11⅛	2	10	1	3	1	10⅝	2	6	1	1½	3	4½	2	3	8.8	.09
1	----	4	6	3	0	4	4⅞	2	0	2	9¼	3	0	2	3	3	9	2	3	16.1	.35
1½	----	4	9	3	2	4	7⅞	2	6	3	4⅜	3	0	2	3	3	9	2	3	24.6	.51
2	----	5	0	3	4	4	10⅞	3	0	3	11½	3	0	2	3	3	9	2	3	33.1	.66
3	----	5	6	3	8	5	4¾	4	0	5	1⅞	3	0	2	3	3	9	2	3	50.4	.97
4	----	6	0	4	0	5	10⅝	5	0	6	4¼	3	0	2	3	3	9	2	3	67.9	1.26
6	----	7	0	4	8	6	10⅜	7	0	8	9	3	0	2	3	3	9	2	3	103.5	2.63
8	----	8	0	5	4	7	10⅛	9	0	11	1¾	3	0	2	3	3	9	2	3	139.5	4.62

Discharge through the Parshall measuring flume can occur under two different conditions of flow: First, where there is no submergence, called free flow; and second, where the elevation of the water surface downstream from the flume is high enough to retard the rate of discharge, a condition called submerged flow. To determine the rate of discharge through this device, two depth gages, H_a and H_b, are provided as shown in figure 2. The upper gage, H_a, is located at a point two-thirds the length of the converging section, A, measured back from the end point of the crest; the lower gage, H_b, is near the downstream end of the throat section. Both gages, H_a and H_b, are to be set with the zero points at the mean elevation of the crest of the flume.

FREE FLOW

Free flow is that condition under which the rate of discharge is dependent solely upon the length of crest and the depth of water at the gage point H_a, in the converging section. One of the important characteristics of the Parshall measuring flume is its ability to withstand a relatively high degree of submergence, over a rather wide range of backwater conditions downstream from the structure, without reduction in the indicated rate of free flow. The stream passing through the throat and diverging sections of the flume can flow at two different stages: first, the condition where the water at high velocity moves in a thin sheet conforming closely to the dip at the lower end of the throat (indicated by Q in fig. 2); second, the condition where the backwater raises the water surface to elevation P, causing a ripple or wave to form at or just downstream from the end of the throat. For this higher stage, P, there occurs a marked reduction in the velocity of the water as it leaves the lower end of the flume.

As regards these two limiting conditions of flow, it is important to note that if the ratio of the H_b head to the H_a head is 0.7 or less, for the 1- to 8-foot flumes, or 0.6 for the 3-, 6-, and 9-inch flumes, the rate of discharge is that given in table 6 for the particular value of the H_a head and the size of flume in use. The ratio H_b to H_a is found by dividing the value of the depth or head at H_b by the depth as measured at H_a. Table 6 gives the rates of discharge in second-feet through this flume for sizes ranging from a 3-inch throat width to that of 8 feet. The 3-inch flume is intended for the accurate measurements of small flows down to approximately one thirty-fifth second-foot as a minimum. To illustrate the determination of the degree of submergence and rate of discharge, let it be assumed that for a 2-foot flume the H_a head is 2.13 feet and H_b is 1.30 feet. The ratio H_b to H_a is 1.30 divided by 2.13, or 0.61. Since this value is less than 0.7, the discharge shown in table 6 is 25.8 second-feet.

Table 6.—*Free-flow discharge table for Parshall measuring flume*

[Letters H_a and W, refer to fig. 2. To convert decimal fractions of a foot to inches and fractions, see corresponding units in table 2]

Head, H_a (feet)	Discharge, Q, for throat widths, W, of—									
	3 inches	6 inches	9 inches	1 foot	1.5 feet	2 feet	3 feet	4 feet	6 feet	8 feet
	Sec.-ft.	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*
0.10	0.028	0.05	0.09	--------	--------	--------	--------	--------	--------	--------
.11	.033	.06	.10	--------	--------	--------	--------	--------	--------	--------
.12	.037	.07	.12	--------	--------	--------	--------	--------	--------	--------
.13	.042	.08	.14	--------	--------	--------	--------	--------	--------	--------
.14	.047	.09	.15	--------	--------	--------	--------	--------	--------	--------
.15	.053	.10	.17	--------	--------	--------	--------	--------	--------	--------
.16	.058	.11	.19	--------	--------	--------	--------	--------	--------	--------
.17	.064	.12	.20	--------	--------	--------	--------	--------	--------	--------
.18	.070	.14	.22	--------	--------	--------	--------	--------	--------	--------
.19	.076	.15	.24	--------	--------	--------	--------	--------	--------	--------
.20	.082	.16	.26	0.35	0.51	0.66	0.97	1.26	--------	--------
.21	.089	.18	.28	.37	.55	.71	1.04	1.36	--------	--------
.22	.095	.19	.30	.40	.59	.77	1.12	1.47	--------	--------
.23	.102	.20	.32	.43	.63	.82	1.20	1.58	--------	--------
.24	.109	.22	.35	.46	.67	.88	1.28	1.69	--------	--------
.25	.117	.23	.37	.49	.71	.93	1.37	1.80	2.63	--------
.26	.124	.25	.39	.51	.76	.99	1.46	1.91	2.80	--------
.27	.131	.26	.41	.54	.80	1.05	1.55	2.03	2.97	--------
.28	.138	.28	.44	.58	.85	1.11	1.64	2.15	3.15	--------
.29	.146	.29	.46	.61	.90	1.18	1.73	2.27	3.33	--------
.30	.154	.31	.49	.64	.94	1.24	1.82	2.39	3.52	4.62
.31	.162	.32	.51	.68	.99	1.30	1.92	2.52	3.71	4.88
.32	.170	.34	.54	.71	1.04	1.37	2.02	2.65	3.90	5.13
.33	.179	.36	.56	.74	1.09	1.44	2.12	2.78	4.10	5.39
.34	.187	.38	.59	.77	1.14	1.50	2.22	2.92	4.30	5.66
.35	.196	.39	.62	.80	1.19	1.57	2.32	3.06	4.50	5.93
.36	.205	.41	.64	.84	1.25	1.64	2.42	3.20	4.71	6.20
.37	.213	.43	.67	.88	1.30	1.72	2.53	3.34	4.92	6.48
.38	.222	.45	.70	.92	1.36	1.79	2.64	3.48	5.13	6.76
.39	.231	.47	.73	.95	1.41	1.86	2.75	3.62	5.35	7.05
.40	.241	.48	.76	.99	1.47	1.93	2.86	3.77	5.57	7.34
.41	.250	.50	.78	1.03	1.53	2.01	2.97	3.92	5.80	7.64
.42	.260	.52	.81	1.07	1.58	2.09	3.08	4.07	6.02	7.94
.43	.269	.54	.84	1.11	1.64	2.16	3.29	4.22	6.25	8.24
.44	.279	.56	.87	1.15	1.70	2.24	3.32	4.38	6.48	8.55
.45	.289	.58	.90	1.19	1.76	2.32	3.44	4.54	6.72	8.87
.46	.299	.61	.94	1.23	1.82	2.40	3.56	4.70	6.96	9.19
.47	.309	.63	.97	1.27	1.88	2.48	3.68	4.86	7.20	9.51
.48	.319	.65	1.00	1.31	1.94	2.57	3.80	5.03	7.44	9.84
.49	.329	.67	1.03	1.35	2.00	2.65	3.92	5.20	7.69	10.2
.50	.339	.69	1.06	1.39	2.06	2.73	4.05	5.36	7.94	10.5
.51	.350	.71	1.10	1.44	2.13	2.82	4.18	5.53	8.20	10.9
.52	.361	.73	1.13	1.48	2.19	2.90	4.31	5.70	8.46	11.2
.53	.371	.76	1.16	1.52	2.25	2.99	4.44	5.88	8.72	11.5
.54	.382	.78	1.20	1.57	2.32	3.08	4.57	6.05	8.98	11.9
.55	.393	.80	1.23	1.62	2.39	3.17	4.70	6.23	9.25	12.2
.56	.404	.82	1.26	1.66	2.45	3.26	4.84	6.41	9.52	12.6
.57	.415	.85	1.30	1.70	2.52	3.35	4.98	6.59	9.79	13.0
.58	.427	.87	1.33	1.75	2.59	3.44	5.11	6.77	10.1	13.3
.59	.438	.89	1.37	1.80	2.66	3.53	5.25	6.96	10.4	13.7
.60	.450	.92	1.40	1.84	2.73	3.62	5.39	7.15	10.6	14.1
.61	.462	.94	1.44	1.88	2.80	3.72	5.53	7.34	10.9	14.5
.62	.474	.97	1.48	1.93	2.87	3.81	5.68	7.53	11.2	14.8
.63	.485	.99	1.51	1.98	2.95	3.91	5.82	7.72	11.5	15.2
.64	.497	1.02	1.55	2.03	3.02	4.01	5.97	7.91	11.8	15.6
.65	.509	1.04	1.59	2.08	3.09	4.11	6.12	8.11	12.1	16.0
.66	.522	1.07	1.63	2.13	3.17	4.20	6.26	8.31	12.4	16.4
.67	.534	1.10	1.66	2.18	3.24	4.30	6.41	8.51	12.7	16.8
.68	.546	1.12	1.70	2.23	3.31	4.40	6.56	8.71	13.0	17.2
.69	.558	1.15	1.74	2.28	3.39	4.50	6.71	8.91	13.3	17.6
.70	.571	1.17	1.78	2.33	3.46	4.60	6.86	9.11	13.6	18.0
.71	.584	1.20	1.82	2.38	3.54	4.70	7.02	9.32	13.9	18.5
.72	.597	1.23	1.86	2.43	3.62	4.81	7.17	9.53	14.2	18.9
.73	.610	1.26	1.90	2.48	3.69	4.91	7.33	9.74	14.5	19.3
.74	.623	1.28	1.94	2.53	3.77	5.02	7.49	9.95	14.9	19.7
.75	.636	1.31	1.98	2.58	3.85	5.12	7.65	10.2	15.2	20.1
.76	.649	1.34	2.02	2.63	3.93	5.23	7.81	10.4	15.5	20.6
.77	.662	1.36	2.06	2.68	4.01	5.34	7.97	10.6	15.8	21.0
.78	.675	1.39	2.10	2.74	4.09	5.44	8.13	10.8	16.2	21.5
.79	.689	1.42	2.14	2.80	4.17	5.55	8.30	11.0	16.5	21.9

TABLE 6.—*Free-flow discharge table for Parshall measuring flume*—Continued

Head, H_a (feet)	Discharge, Q, for throat widths, W, of—									
	3 inches	6 inches	9 inches	1 foot	1.5 feet	2 feet	3 feet	4 feet	6 feet	8 feet
	Sec.-ft.	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*
0.80	0.702	1.45	2.18	2.85	4.26	5.66	8.46	11.3	16.8	22.4
.81	.716	1.48	2.22	2.90	4.34	5.77	8.63	11.5	17.2	22.8
.82	.730	1.50	2.27	2.96	4.42	5.88	8.79	11.7	17.5	23.3
.83	.744	1.53	2.31	3.02	4.50	6.00	8.96	11.9	17.8	23.7
.84	.757	1.56	2.35	3.07	4.59	6.11	9.13	12.2	18.2	24.2
.85	.771	1.59	2.39	3.12	4.67	6.22	9.30	12.4	18.5	24.6
.86	.786	1.62	2.44	3.18	4.76	6.33	9.48	12.6	18.9	25.1
.87	.800	1.65	2.48	3.24	4.84	6.44	9.65	12.8	19.2	25.6
.88	.814	1.68	2.52	3.29	4.93	6.56	9.82	13.1	19.6	26.1
.89	.828	1.71	2.57	3.35	5.01	6.68	10.0	13.3	19.9	26.5
.90	.843	1.74	2.61	3.41	5.10	6.80	10.2	13.6	20.3	27.0
.91	.858	1.77	2.66	3.46	5.19	6.92	10.4	13.8	20.7	27.5
.92	.872	1.81	2.70	3.52	5.28	7.03	10.5	14.0	21.0	28.0
.93	.887	1.84	2.75	3.58	5.37	7.15	10.7	14.3	21.4	28.5
.94	.902	1.87	2.79	3.64	5.46	7.27	10.9	14.5	21.8	29.0
.95	.916	1.90	2.84	3.70	5.55	7.39	11.1	14.8	22.1	29.5
.96	.931	1.93	2.88	3.76	5.64	7.51	11.3	15.0	22.5	30.0
.97	.946	1.97	2.93	3.82	5.73	7.63	11.4	15.3	22.9	30.5
.98	.961	2.00	2.98	3.88	5.82	7.75	11.6	15.5	23.2	31.0
.99	.977	2.03	3.02	3.94	5.91	7.88	11.8	15.8	23.6	31.5
1.00	.992	2.06	3.07	4.00	6.00	8.00	12.0	16.0	24.0	32.0
1.01	1.01	2.09	3.12	4.06	6.09	8.12	12.2	16.3	24.4	32.5
1.02	1.02	2.12	3.17	4.12	6.19	8.25	12.4	16.5	24.8	33.0
1.03	1.04	2.16	3.21	4.18	6.28	8.38	12.6	16.8	25.2	33.6
1.04	1.05	2.19	3.26	4.25	6.37	8.50	12.8	17.0	25.6	34.1
1.05	1.07	2.22	3.31	4.31	6.47	8.63	13.0	17.3	25.9	34.6
1.06	1.09	2.26	3.36	4.37	6.56	8.76	13.2	17.5	26.3	35.1
1.07	1.10	2.29	3.40	4.43	6.66	8.88	13.3	17.8	26.7	35.7
1.08	1.12	2.32	3.45	4.50	6.75	9.01	13.5	18.1	27.1	36.2
1.09	1.13	2.36	3.50	4.56	6.85	9.14	13.7	18.3	27.5	36.8
1.10	----------	2.40	3.55	4.62	6.95	9.27	13.9	18.6	27.9	37.3
1.11	----------	2.43	3.60	4.68	7.04	9.40	14.1	18.9	28.4	37.8
1.12	----------	2.46	3.65	4.75	7.14	9.54	14.3	19.1	28.8	38.4
1.13	----------	2.50	3.70	4.82	7.24	9.67	14.5	19.4	29.2	38.9
1.14	----------	2.53	3.75	4.88	7.34	9.80	14.7	19.7	29.6	39.5
1.15	----------	2.57	3.80	4.94	7.44	9.94	14.9	19.9	30.0	40.1
1.16	----------	2.60	3.85	5.01	7.54	10.1	15.1	20.2	30.4	40.6
1.17	----------	2.64	3.90	5.08	7.64	10.2	15.3	20.5	30.8	41.2
1.18	----------	2.68	3.95	5.15	7.74	10.3	15.6	20.8	31.3	41.8
1.19	----------	2.71	4.01	5.21	7.84	10.5	15.8	21.1	31.7	42.3
1.20	----------	2.75	4.06	5.28	7.94	10.6	16.0	21.3	32.1	42.9
1.21	----------	2.78	4.11	5.34	8.05	10.8	16.2	21.6	32.5	43.5
1.22	----------	2.82	4.16	5.41	8.15	10.9	16.4	21.9	33.0	44.1
1.23	----------	2.86	4.22	5.48	8.25	11.0	16.6	22.2	33.4	44.6
1.24	----------	2.89	4.27	5.55	8.36	11.2	16.8	22.5	33.8	45.2
1.25	----------	2.93	4.32	5.62	8.46	11.3	17.0	22.8	34.3	45.8
1.26	----------	2.97	4.37	5.69	8.56	11.5	17.2	23.0	34.7	46.4
1.27	----------	3.01	4.43	5.76	8.67	11.6	17.4	23.3	35.1	47.0
1.28	----------	3.04	4.48	5.82	8.77	11.7	17.7	23.6	35.6	47.6
1.29	----------	3.08	4.53	5.89	8.88	11.9	17.9	23.9	36.0	48.2
1.30	----------	3.12	4.59	5.96	8.99	12.0	18.1	24.2	36.5	48.8
1.31	----------	3.16	4.64	6.03	9.09	12.2	18.3	24.5	36.9	49.4
1.32	----------	3.19	4.69	6.10	9.20	12.3	18.5	24.8	37.4	50.0
1.33	----------	3.23	4.75	6.18	9.30	12.4	18.8	25.1	37.8	50.6
1.34	----------	3.27	4.80	6.25	9.41	12.6	19.0	25.4	38.3	51.2
1.35	----------	3.31	4.86	6.32	9.52	12.7	19.2	25.7	38.7	51.8
1.36	----------	3.35	4.92	6.39	9.63	12.9	19.4	26.0	39.2	52.5
1.37	----------	3.39	4.97	6.46	9.74	13.0	19.6	26.3	39.7	53.1
1.38	----------	3.43	5.03	6.53	9.85	13.2	19.9	26.6	40.1	53.7
1.39	----------	3.47	5.08	6.60	9.96	13.3	20.1	26.9	40.6	54.3
1.40	----------	3.51	5.14	6.68	10.1	13.5	20.3	27.2	41.1	55.0
1.41	----------	3.55	5.19	6.75	10.2	13.6	20.6	27.5	41.5	55.6
1.42	----------	3.59	5.25	6.82	10.3	13.8	20.8	27.8	42.0	56.2
1.43	----------	3.63	5.31	6.89	10.4	13.9	21.0	28.1	42.5	56.9
1.44	----------	3.67	5.37	6.97	10.5	14.1	21.2	28.5	42.9	57.5
1.45	----------	3.71	5.42	7.04	10.6	14.2	21.5	28.8	43.4	58.1
1.46	----------	3.75	5.48	7.12	10.7	14.4	21.7	29.1	43.9	58.8
1.47	----------	3.79	5.54	7.19	10.8	14.5	21.9	29.4	44.4	59.4
1.48	----------	3.83	5.59	7.26	11.0	14.7	22.2	29.7	44.9	60.1
1.49	----------	3.87	5.65	7.34	11.1	14.9	22.4	30.0	45.3	60.7

414241°—41——3

TABLE 6.—*Free-flow discharge table for Parshall measuring flume*—Continued

Head, H_a (feet)	Discharge, Q, for throat widths, W, of—									
	3 inches	6 inches	9 inches	1 foot	1.5 feet	2 feet	3 feet	4 feet	6 feet	8 feet
	Sec.-ft.	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*
1.50			5.71	7.41	11.2	15.0	22.6	30.3	45.8	61.4
1.51			5.77	7.49	11.3	15.2	22.9	30.7	46.3	62.1
1.52			5.83	7.57	11.4	15.3	23.1	31.0	46.8	62.7
1.53			5.89	7.64	11.5	15.5	23.4	31.3	47.3	63.4
1.54			5.94	7.72	11.7	15.6	23.6	31.6	47.8	64.0
1.55			6.00	7.80	11.8	15.8	23.8	32.0	48.3	64.7
1.56			6.06	7.87	11.9	15.9	24.1	32.3	48.8	65.4
1.57			6.12	7.95	12.0	16.1	24.3	32.6	49.3	66.1
1.58			6.18	8.02	12.1	16.3	24.6	32.9	49.8	66.7
1.59			6.24	8.10	12.2	16.4	24.8	33.3	50.3	67.4
1.60			6.31	8.18	12.4	16.6	25.1	33.6	50.8	68.1
1.61			6.37	8.26	12.5	16.7	25.3	33.9	51.3	68.8
1.62			6.43	8.34	12.6	16.9	25.5	34.3	51.8	69.5
1.63			6.49	8.42	12.7	17.1	25.8	34.6	52.3	70.2
1.64			6.55	8.49	12.8	17.2	26.0	34.9	52.8	70.9
1.65			6.61	8.57	13.0	17.4	26.3	35.3	53.3	71.6
1.66			6.67	8.65	13.1	17.6	26.5	35.6	53.9	72.3
1.67			6.73	8.73	13.2	17.7	26.8	35.9	54.4	73.0
1.68			6.79	8.81	13.3	17.9	27.0	36.3	54.9	73.7
1.69			6.86	8.89	13.5	18.0	27.3	36.6	55.4	74.4
1.70			6.92	8.97	13.6	18.2	27.6	37.0	56.0	75.1
1.71			6.98	9.05	13.7	18.4	27.8	37.3	56.5	75.8
1.72			7.04	9.13	13.8	18.5	28.1	37.7	57.0	76.5
1.73			7.11	9.21	13.9	18.7	28.3	38.0	57.5	77.2
1.74			7.17	9.29	14.1	18.9	28.6	38.3	58.1	77.9
1.75			7.23	9.38	14.2	19.0	28.8	38.7	58.6	78.7
1.76			7.29	9.46	14.3	19.2	29.1	39.0	59.1	79.4
1.77			7.36	9.54	14.4	19.4	29.3	39.4	59.7	80.1
1.78			7.42	9.62	14.6	19.6	29.6	39.7	60.2	80.8
1.79			7.48	9.70	14.7	19.7	29.9	40.1	60.7	81.6
1.80			7.54	9.79	14.8	19.9	30.1	40.5	61.3	82.3
1.81			7.61	9.87	15.0	20.1	30.4	40.8	61.8	83.0
1.82			7.68	9.95	15.1	20.2	30.7	41.2	62.4	83.8
1.83			7.74	10.0	15.2	20.4	30.9	41.5	62.9	84.5
1.84			7.81	10.1	15.3	20.6	31.2	41.9	63.5	85.3
1.85			7.87	10.2	15.5	20.8	31.5	42.2	64.0	86.0
1.86			7.94	10.3	15.6	20.9	31.7	42.6	64.6	86.8
1.87			8.00	10.4	15.7	21.1	32.0	43.0	65.1	87.5
1.88			8.06	10.5	15.8	21.3	32.3	43.3	65.7	88.3
1.89			8.13	10.5	16.0	21.5	32.5	43.7	66.3	89.0
1.90			8.20	10.6	16.1	21.6	32.8	44.1	66.8	89.8
1.91			8.26	10.7	16.2	21.8	33.1	44.4	67.4	90.5
1.92			8.33	10.8	16.4	22.0	33.3	44.8	67.9	91.3
1.93			8.40	10.9	16.5	22.2	33.6	45.2	68.5	92.1
1.94			8.46	11.0	16.6	22.4	33.9	45.5	69.1	92.8
1.95			8.52	11.1	16.7	22.5	34.1	45.9	69.6	93.6
1.96			8.59	11.1	16.9	22.7	34.4	46.3	70.2	94.4
1.97			8.66	11.2	17.0	22.9	34.7	46.6	70.8	95.1
1.98			8.73	11.3	17.2	23.1	35.0	47.0	71.4	95.9
1.99			8.80	11.4	17.3	23.2	35.3	47.4	71.9	96.7
2.00				11.5	17.4	23.4	35.5	47.8	72.5	97.5
2.01				11.6	17.6	23.6	35.8	48.1	73.1	98.3
2.02				11.7	17.7	23.8	36.1	48.5	73.7	99.1
2.03				11.8	17.8	24.0	36.4	48.9	74.2	99.8
2.04				11.8	18.0	24.2	36.7	49.3	74.8	100.6
2.05				11.9	18.1	24.3	36.9	49.7	75.4	101.4
2.06				12.0	18.2	24.5	37.2	50.1	76.0	102.2
2.07				12.1	18.4	24.7	37.5	50.4	76.6	103.0
2.08				12.2	18.5	24.9	37.8	50.8	77.2	103.8
2.09				12.3	18.7	25.1	38.1	51.2	77.8	104.6
2.10				12.4	18.8	25.3	38.4	51.6	78.4	105.4
2.11				12.5	18.9	25.5	38.6	52.0	79.0	106.2
2.12				12.6	19.0	25.6	38.9	52.4	79.6	107.0
2.13				12.6	19.2	25.8	39.2	52.8	80.2	107.9
2.14				12.7	19.3	26.0	39.5	53.2	80.8	108.7
2.15				12.8	19.5	26.2	39.8	53.5	81.4	109.5
2.16				12.9	19.6	26.4	40.1	53.9	82.0	110.3
2.17				13.0	19.7	26.6	40.4	54.3	82.6	111.1
2.18				13.1	19.9	26.8	40.7	54.7	83.2	111.9
2.19				13.2	20.0	27.0	41.0	55.1	83.8	112.8

TABLE 6.—*Free-flow discharge table for Parshall measuring flume*—Continued

Head, H_a (feet)	Discharge, Q, for throat widths, W, of—									
	3 inches	6 inches	9 inches	1 foot	1.5 feet	2 feet	3 feet	4 feet	6 feet	8 feet
	Sec.-ft.	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*
2.20				13.3	20.2	27.2	41.3	55.5	84.4	113.6
2.21				13.4	20.3	27.3	41.5	55.9	85.0	114.4
2.22				13.5	20.5	27.5	41.8	56.3	85.6	115.3
2.23				13.6	20.6	27.7	42.1	56.7	86.3	116.1
2.24				13.7	20.7	27.9	42.4	57.1	86.9	116.9
2.25				13.7	20.9	28.1	42.7	57.5	87.5	117.8
2.26				13.8	21.0	28.3	43.0	57.9	88.1	118.6
2.27				13.9	21.2	28.5	43.3	58.3	88.7	119.5
2.28				14.0	21.3	28.7	43.6	58.7	89.4	120.3
2.29				14.1	21.4	28.9	43.9	59.2	90.0	121.2
2.30				14.2	21.6	29.1	44.2	59.6	90.6	122.0
2.31				14.3	21.7	29.3	44.5	60.0	91.2	122.9
2.32				14.4	21.9	29.5	44.8	60.4	91.9	123.7
2.33				14.5	22.0	29.7	45.1	60.8	92.5	124.6
2.34				14.6	22.2	29.9	45.4	61.2	93.1	125.4
2.35				14.7	22.4	30.1	45.7	61.6	93.8	126.3
2.36				14.8	22.5	30.3	46.0	62.0	94.4	127.2
2.37				14.9	22.6	30.5	46.4	62.4	95.1	128.0
2.38				15.0	22.8	30.7	46.7	62.9	95.7	128.9
2.39				15.1	22.9	30.9	47.0	63.3	96.3	129.8
2.40				15.2	23.0	31.1	47.3	63.7	97.0	130.7
2.41				15.3	23.2	31.3	47.6	64.1	97.6	131.5
2.42				15.4	23.3	31.5	47.9	64.5	98.3	132.4
2.43				15.5	23.5	31.7	48.2	65.0	98.9	133.3
2.44				15.6	23.7	31.9	48.5	65.4	99.6	134.2
2.45				15.6	23.8	32.1	48.8	65.8	100.2	135.1
2.46				15.7	23.9	32.3	49.1	66.2	100.9	135.9
2.47				15.9	24.1	32.5	49.5	66.7	101.5	136.8
2.48				15.9	24.2	32.7	49.8	67.1	102.2	137.7
2.49				16.0	24.4	32.9	50.1	67.5	102.8	138.6
2.50				16.1	24.6	33.1	50.4	67.9	103.5	139.5

SUBMERGED FLOW

When the ratio of H_b to H_a readings exceeds 0.7 for flumes of throat widths ranging from 1 to 8 feet, and 0.6 for those less than 1 foot, it becomes necessary to apply a negative correction to the free-flow discharge, as given in table 6, in order to determine the rate of submerged flow. This computed submerged flow through any particular size of flume is determined by the use of the appropriate correction diagrams shown as figures 3, 4, 5, and 6. The correction diagram for the 1-foot flume (fig. 6) is made applicable to the larger flumes by multiplying the correction for the 1-foot flume by the factor given below for the particular flume in use.

Size of flume, W (feet):	*Multiplying factor, M*
1	1.0
1.5	1.4
2	1.8
3	2.4
4	3.1
6	4.3
8	5.4

The following examples illustrate the method of computing submerged-flow discharge through the Parshall measuring flume by use of the correction diagram: What will be the discharge through a 1-foot flume with an H_a head of 1.60 feet and H_b at 1.41 feet? The ratio 1.41/1.60 is approximately 0.88, or 88 percent. At the left margin of the diagram (fig. 6) enter at the value 1.60 and then follow hori-

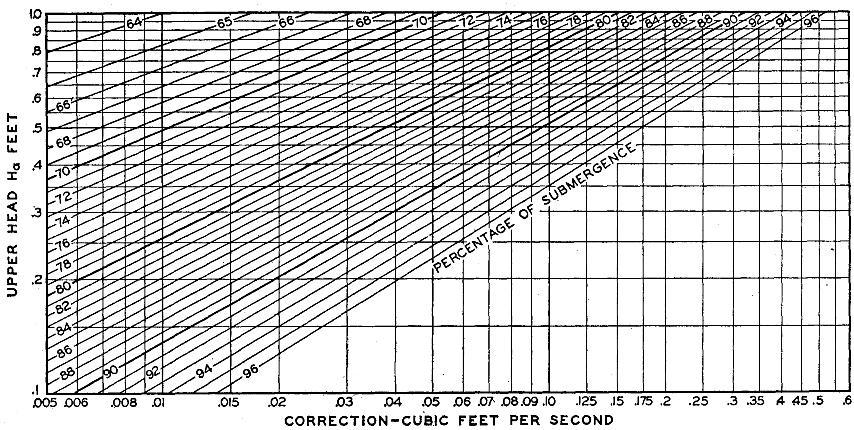


FIGURE 3.—Diagram for computing submerged flow through a 3-inch Parshall measuring flume.

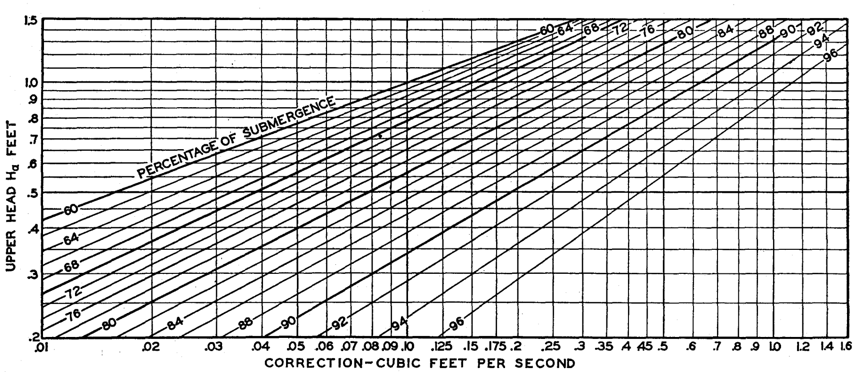


FIGURE 4.—Diagram for computing submerged flow through a 6-inch Parshall measuring flume.

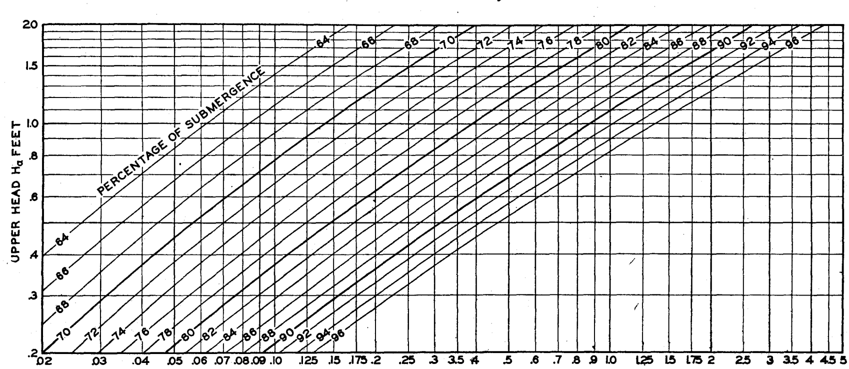


FIGURE 5.—Diagram for computing submerged flow through a 9-inch Parshall measuring flume.

zontally to the right until intersecting the "percentage of submergence" line "88." Now follow vertically downward to the base of the diagram and observe the correction value of 1.80 second-feet, which is the amount to be subtracted from the free-flow discharge as given in table 6. Therefore, the submerged-flow discharge will be 8.18−1.80, or 6.38 second-feet.

As another example, let it be assumed that the quantity to be ascertained is the submerged-flow discharge through a 3-foot flume having H_a at 2.10 feet and H_b at 2.00 feet. Here the ratio 2.00/2.10 is very closely 0.95 or 95 percent. As before, enter the diagram at the left, at the value H_a equals 2.10, and follow horizontally to the right. In this case the "percentage of submergence" line "95" is not shown in the diagram; however, the interval between these curved lines is obviously equivalent to 2 percent, and since the last line is 94, by continuing to the right one-half of the interval we reach the approximate

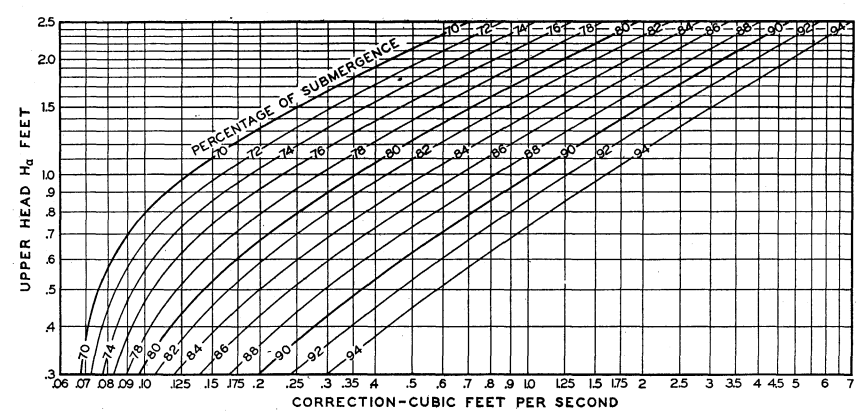


FIGURE 6.—Diagram for computing submerged flow through a 1-foot Parshall measuring flume.

location of the correction factor. Vertically below this point, on the base of the diagram, is found the correction 5.75 second-feet. This is the amount of correction for a 1-foot flume. However, since the 3-foot flume is used it will be necessary to multiply this amount by 2.4, as given in the tabulation (shown above), to obtain the full correction, which for a flume of this size is 5.75 by 2.4, or 13.8 second-feet. From table 6 the free-flow discharge through a 3-foot flume for an H_a head of 2.10 feet is found to be 38.4 second-feet, and the submerged flow is therefore 38.4−13.8, or 24.6 second-feet.

The submerged flow through a 6-foot flume with H_a at 1.79 feet and H_b at 1.65 feet is found by use of the correction diagram to be 46.7 second-feet.

For the small flumes (i. e., those having less than 1-foot throat widths) the same method of computing the submerged flow is followed. For example: What is the discharge through a 6-inch flume with an H_a head of 1.38 feet and H_b at 1.20 feet? In this case the ratio of the heads is 87 percent. The correction for this degree of submergence (fig. 4) is found to be 0.90 second-foot, and the computed flow is 3.43−0.90, or 2.53 second-feet.

SETTING AND SIZE

The successful operation of the Parshall measuring flume depends upon setting the crest at the correct elevation with reference to the bed of the channel. Where sufficient fall is available this setting may be determined with little difficulty, but if the fall or grade of the channel is slight, care must be taken in fixing the height of the crest so that if possible, the degree of submergence shall not exceed the limits of free-flow operation as explained on page 13. If conditions will not permit free-flow operation the setting should be made so that minimum submergence will exist. It is necessary in all cases to set the crest so that the degree of submergence shall not exceed the practical limit of about 95 percent since the flume will not measure dependably if the submergence is greater. The elevation of the crest of the flume depends upon both the quantity of water to be measured and the size of the flume.

The selection of the location or site of the structure is sometimes important. Generally, it is best to have it conveniently near the point of diversion or regulating gate if conditions of operation require frequent notation of discharge. The flume should not be placed too

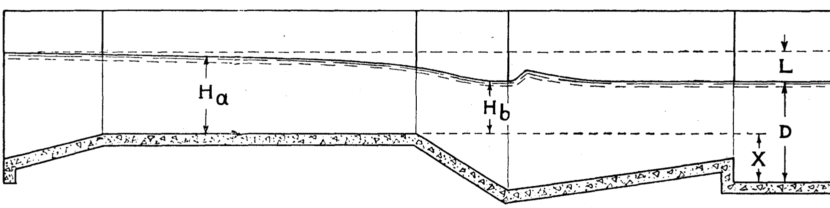


FIGURE 7.—Section of a Parshall measuring flume illustrating the determination of the proper crest elevation.

near the headgate as the disturbed water just downstream from the gate may cause surging and unbalanced flow; the structure had best be in a straight section of the channel.

Following the selection of the site for the flume it is necessary to determine the size and proper elevation of the crest. For example: 20 second-feet is to be measured in a channel of moderate grade where the water depth is 2.5 feet. This quantity of flow can be measured through several sizes of flume, but for the sake of economy the smallest practical size should be selected. First, let it be assumed that a submergence of 70 percent shall not be exceeded in order that the flow may be determined by the single gage reading of H_a.

To meet these requirements three different sizes of flumes and settings will be investigated. First, for a 4-foot flume and a discharge of 20 second-feet, the H_a head, is found to be 1.15 feet (table 6). For a submergence of 70 percent, the ratio of H_b gage to H_a gage is 0.7; hence H_b for this condition of flow is 0.81 foot. At 70 percent submergence the water surface in the throat, at the H_b gage, is essentially level with that at the lower end of the flume. Under this condition of flow the water depth just below the structure will be approximately the same as before the flume was installed; that is, 2.5 feet. In figure 7, the dimension D, represents this depth of 2.5 feet. By subtracting H_b or 0.81 foot from 2.5 feet the value of X, or 1.69 feet, is obtained; this is the elevation of the crest above the bottom of the

channel. For this size of flume, set with the crest at 1.69 feet above the bed of the channel, the flow of 20 second-feet will be at 70 percent submergence and the actual loss of head or difference in elevation between the upstream and downstream water surfaces will be 0.40 foot, as determined by figure 8. The depth of water upstream from the structure at a flow of 20 second-feet will therefore be 2.90 feet. It will be necessary to examine the freeboard of the channel, as well as the effect of the rise of the water surface upon the flow through the headgate in deciding which is the most practical size of flume to use.

Second, for a 3-foot flume and discharge of 20 second-feet, the H_a head is found to be 1.39 feet (table 6). Again for a submergence

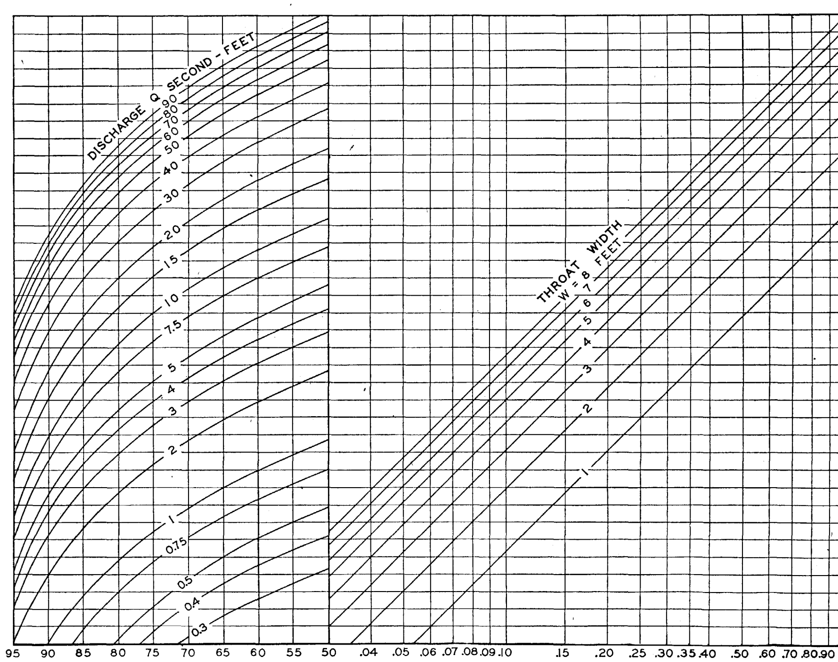


FIGURE 8.—Diagram for determining the loss of head through the Parshall measuring flume, 1- to 8-foot sizes.

of 70 percent, the ratio of H_b to H_a is 0.7; hence, H_a for this condition of flow is 0.97 foot. By reference to figure 7 the value of X or the elevation of the crest above the bottom of the channel is found to be 1.53 feet, and the actual loss of head through the flume (fig. 8) is found to be 0.48 foot. The depth of water upstream for this size of flume will now be 2.98 feet.

Next consider a 2-foot flume: As before, find the H_a head in table 6 for a free flow of 20 second-feet. For the 2-foot flume this head is 1.81 feet. At a submergence of 70 percent the value of H_b is found to be 1.27 feet. By again referring to figure 7, the value of X or the elevation of the crest above the bed of channel is determined to be 2.50−1.27, or 1.23 feet. For this size of flume discharging 20 second-feet at a submergence of 70 percent, the actual loss of head (fig. 8) is 0.62 foot and the depth of water upstream is 3.12 feet.

If it is found that the banks of the channel and entrance conditions through the headgates are satisfactory, the 2-foot flume will be most economical because of its small dimensions; however, when width of channel is considered the final selection may be in favor of the 3- or 4-foot flume because moderate to long wing walls may be required. Usually, the width of the throat of the flume will be from one-third to one-half the width of the channel.

Observable in the above analysis of the three selected sizes of flumes is the fact that the actual increase in the depth of water upstream from the structure is considerably less than the elevation of the crest above the bottom of the channel. For the 4-foot flume the crest is 1.69 feet above the bed of channel and the rise in water upstream

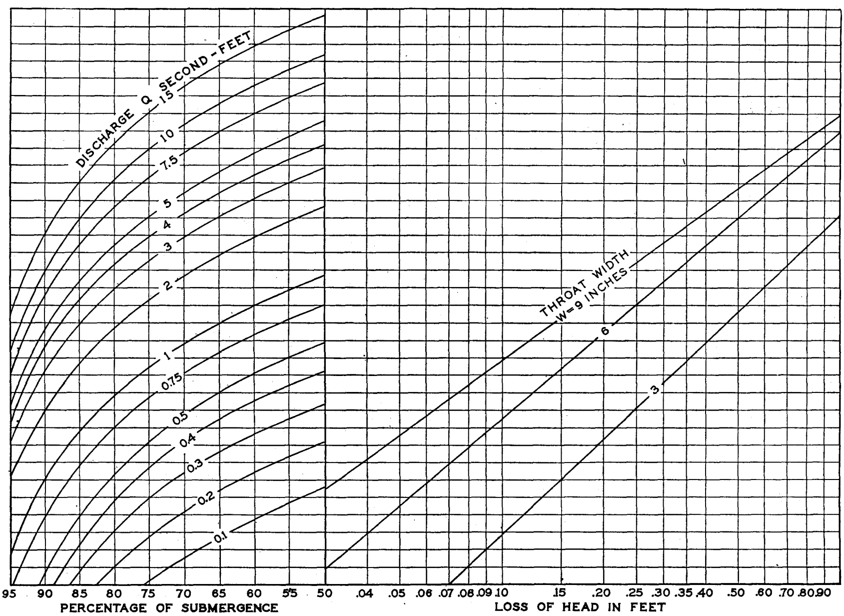


FIGURE 9.—Diagram for determining the loss of head through the Parshall measuring flume, 3-, 6-, and 9-inch sizes.

will be only 0.40 foot or about 24 percent; for the 3-foot flume the rise is about 31 percent; and for the 2-foot flume it is about 50 percent.

This analysis further shows that as the size of flume is decreased, the elevation of the crest becomes less and the depth of water upstream from the structure becomes greater for similar rates of discharge and like degrees of submergence. It is usually best practice to set the flume high rather than low to provide a margin of safety for variations of the water surface downstream. In irrigation channels, especially those with earth banks and bottom, deposits of sand or silt may change the downstream flow conditions, and weeds, willows, or moss may likewise affect the degree of submergence.

In some cases it may be impractical to set the flume for operation under a free-flow condition, because of insufficient grade or other limiting conditions; it then becomes necessary to use both the H_a and H_b gages, as previously explained. The flume may be placed so as to operate at any degree of submergence.

For example, let a 3-foot flume be set to measure a flow of 20 second-feet, with water depth in channel 2.5 feet and submergence 90 percent. To determine the proper elevation of the crest of the flume, as required by these limitations, it will first be necessary to refer to figure 6. For the submerged flow of 20 second-feet, the value of H_a will be somewhat greater than for free flow. Try H_a at 1.50 feet. For this head the free-flow discharge will be 22.6 second-feet. The diagram correction (90 percent submergence) for H_a at 1.50 feet, is about 1.95 second-feet in the case of a 1-foot flume; and for the 3-foot flume will be 2.4 times 1.95, or 4.7 second-feet. This amount subtracted from the free flow of 22.6 second-feet gives a submerged flow of approximately 18 second-feet. Thus the assumed value of H_a is too small.

For H_a at 1.62 feet the computed submerged flow will be found to be substantially correct, and for this condition with H_b head at 0.9 of 1.62 feet or 1.46 feet, figure 7 shows the value of X to be 1.04 feet. For this elevation of the crest (i. e., 1.04 feet above the bottom of the channel) the actual loss of head through the flume will be about 0.18 foot, and the upstream water depth will be approximately 2.7 feet. In this case, with the floor of the converging section of the flume placed slightly more than 1 foot above the bottom of the channel, the increase in the depth of water upstream from the structure is only about 0.2 foot.

Figure 9 shows the loss of head through the 3-, 6-, and 9-inch flumes. The method of determining the proper elevation of the crest of these smaller flumes is identical with that for the larger structures.

CONSTRUCTION

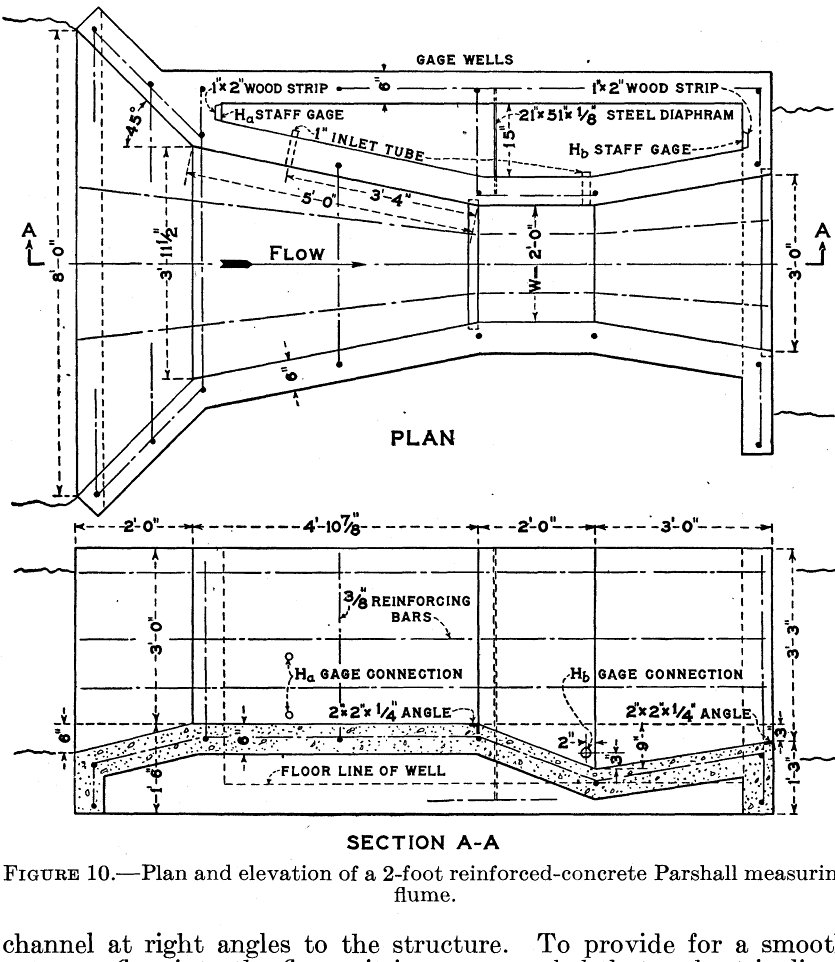
The Parshall measuring flume may be built of timber, concrete, or (in the smaller sizes) sheet metal. The dimensions for the various sizes are given in table 5, the several columns being headed by capital letters referring to the corresponding dimensions shown in figure 2. In the construction of this flume it is necessary to build to exact dimensions especially as regards the converging and throat sections, and the gage points H_a and H_b must be referenced with exactness to table 5.

Flumes of the sizes described in this bulletin made of lumber, must have sills and posts of ample dimensions, with substantial cross ties spanning the top. Figure 2 presents a plan for a frame structure, 1- to 4-foot sizes, with 4- by 4-inch sills and posts, 2- by 6-inch cross ties, and walls and floor of common 2-inch surfaced planking. For the 6- and 8-foot sized flumes, 4- by 6-inch posts and sills and 3-inch surfaced plank walls and floor will be found more satisfactory. Materials pretreated with appropriate preservatives will greatly lengthen the life of the structure. The bottom wall planks should be placed before the floor is laid. This will prevent the side walls from crowding or bulging inward at the botton, which would materially alter the inside dimensions. It is recommended that a ⅛-inch space be left between planks when the floor and walls are being placed, to allow for swelling.

It is essential that the crest be straight and level, and that the floor of the converging section be level in both directions. An

angle-iron crest, as indicated in figure 2, is strongly recommended. This metal piece, which insures a true and definite edge, should be gained in to set flush with the floor line, and should be held firmly in place by heavy screws having countersunk heads.

Suitable wing walls should be provided at both ends of the structure. Those at the upstream end should be built and substantially anchored at angles of about 45° with the axis of the flume. For the smaller flumes, the downstream wings may be extended to the sides of the



SECTION A-A

FIGURE 10.—Plan and elevation of a 2-foot reinforced-concrete Parshall measuring flume.

channel at right angles to the structure. To provide for a smooth entrance flow into the flume, it is recommended that a short inclined floor, with a slope of about 1 to 4, be laid flush with the floor of the converging section, as shown in figure 2. If the material in the bed of the channel is soft, either stone riprap or a wooden apron should be provided at the downstream end of the structure to prevent erosion of the bed and banks.

For permanency, monolithic reinforced-concrete flumes are built in all sizes. Such structures are little subject to expansion or contraction and so insure uniformity in operation.

A suggested design of a small reinforced-concrete flume is shown in figure 10. For this type the two stilling wells, H_a and H_b, are cast as integral parts of the structure. Figure 11 shows a portable wooden form used for casting a 6-inch reinforced-concrete Parshall measuring flume. The pieces forming the inside and outside wall faces are waterproof plywood three-eighths of an inch thick, securely fixed to ¾-inch clear pine boards set edgewise at the top, bottom, and midsection. Crosspieces at the top suspend the inside form at the exact distances needed to make the throat width of true dimension and the walls of uniform thickness. Pieces of 1- by 1- by ⅛-inch angle irons, cut to lengths about 4 inches longer than the true inside dimensions of the flume, are placed at the upstream end of the converging section, the upstream end of the diverging section, and at the crest.

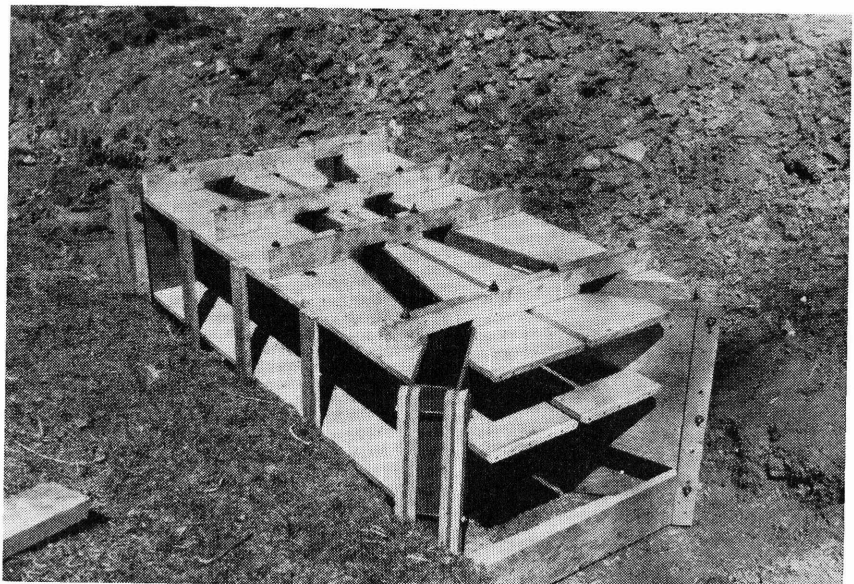


FIGURE 11.—Setting of portable form for casting 6-inch reinforced-concrete Parshall measuring flume.

Twisted looped wires from the top 2- by 4-inch crosspieces hold these metal bars securely in place against the lower edges of the inner suspended forms. The structure is cast monolithically at one pouring, the angle irons serving as guides in the striking of the floors of the various flume sections. Under ordinary conditions the forms may be removed soon after the concrete has received its initial set. To insure smooth wall surfaces, the wet concrete should be well spaded when placed in the forms, and for ease in removing the forms the casting surfaces should be kept well greased.

Figures 12 and 13 show the finished 6-inch flume in operation.

Construction of this flume with sheet metal for the 3-inch to 3-foot sizes has proved satisfactory, but the cost somewhat exceeds that of either concrete or wood. The metal flume has advantage in that it is portable, can be readily reset and readjusted if improperly placed

FIGURE 12.—A 6-inch reinforced-concrete Parshall measuring flume as cast by use of portable form.

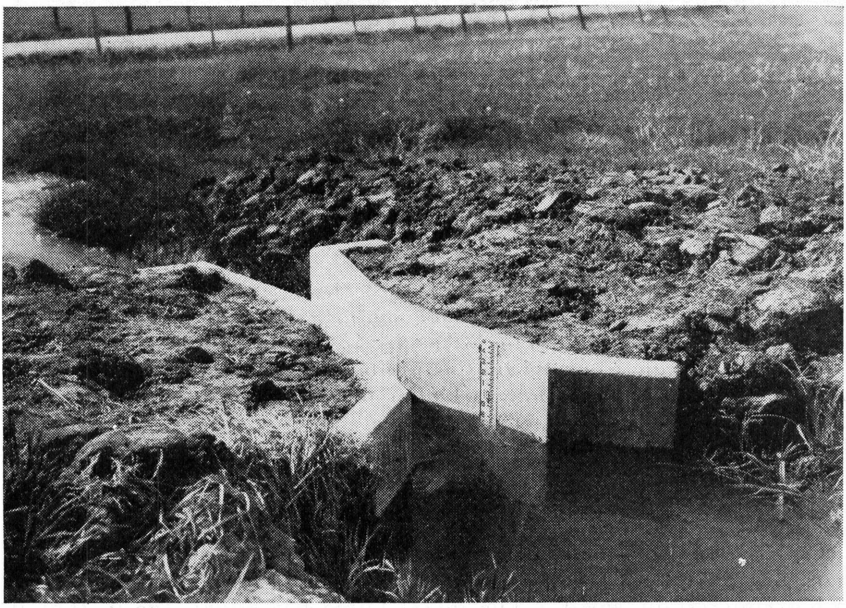


FIGURE 13.—A 6-inch reinforced-concrete Parshall measuring flume, cast by use of portable form—free-flow discharge, 1.36 second-feet.

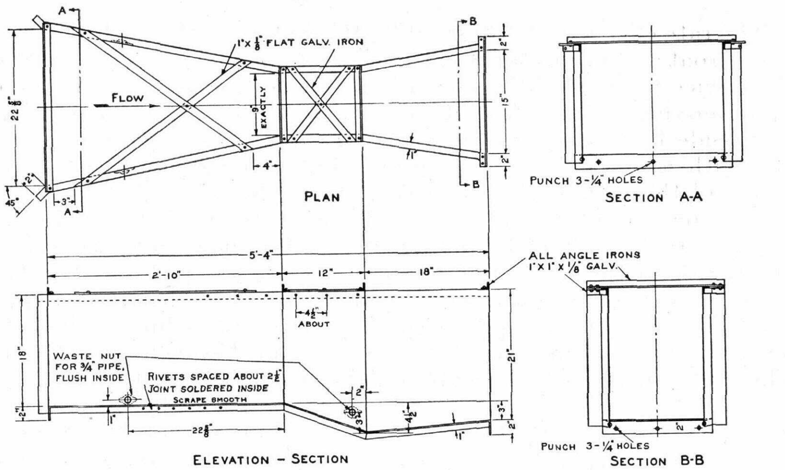


FIGURE 14.—Plan and elevation of a 9-inch sheet-metal Parshall measuring flume.

at the start, and is relatively long-lived and immune from fire hazards such as are occasioned by ditch-cleaning operations. The use of factory-made flumes should assure accuracy of dimensions and uniform construction. Figure 14 is a practical design of a metal flume. A 6-inch metal flume to operate as a free-flow device is shown in figure 15.

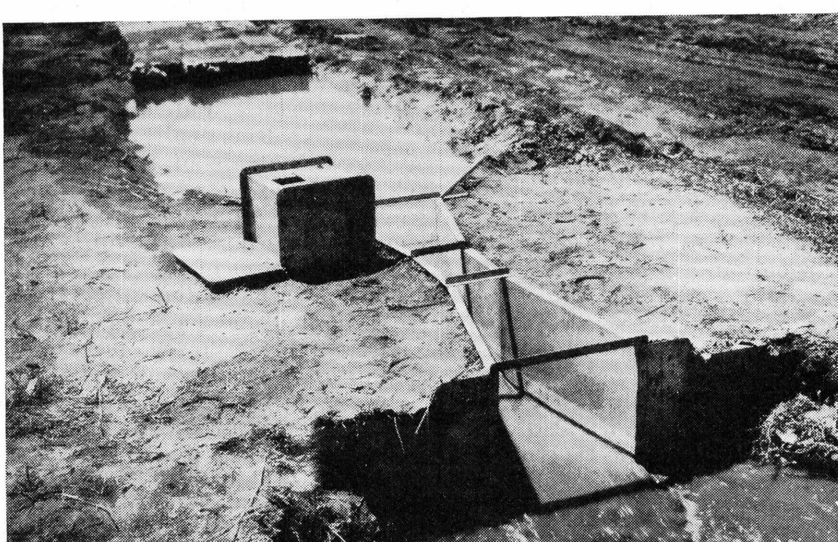


FIGURE 15.—A 6-inch sheet-metal Parshall measuring flume set in a farm lateral—free-flow discharge, 0.75 second-foot.

STILLING WELLS, GAGES, AND RECORDING INSTRUMENTS

The rate of flow is determined by the water depths in the converging and throat sections of the flume. The stream of water flowing through the device varies slightly in depth, owing to the natural pulsations set up in moving water. A staff gage set vertically at the proper point on the inside face of the converging wall can be read as the upper head, H_a, with a fair degree of accuracy, but placing such a gage on the inside of the throat section to observe the lower head, H_b, is impracticable owing to the roughness of the water surface at this place. Because of the symmetry of the flume, the gages may be placed on either side of the structure.

For best results, it is recommended that these heads or depths of water be observed in special compartments or stilling wells set just outside the flume, small inlet tubes connecting the wells with the flume. The staff gage is set vertically on the inside face of the stilling well, with the zero or initial point of the graduated scale level with the crest of the flume. It is preferable to have this gage graduated in feet and in tenths and hundredths of a foot, rather than in feet and inches, to permit convenient reference to the discharge tables and the computation of percentage of submergence.

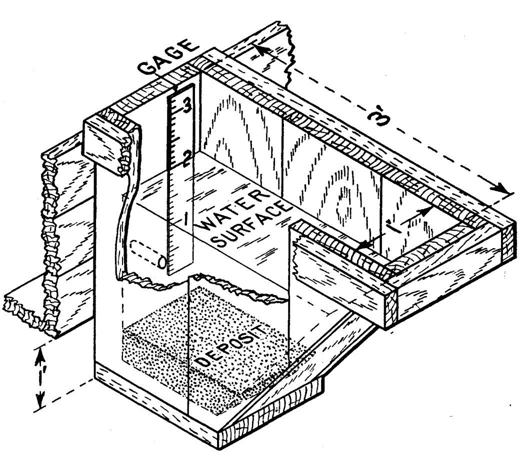


FIGURE 16.—Stilling well with staff gage.

The stilling well (fig. 16) should be made of sound material with four sides and bottom, and set vertically, close to the outside of the flume, as shown in figure 2. At a point back from the end of crest (table 5, 2/3 A) exactly two-thirds of the length of the converging section, a tightly fitting 1-inch tube should be inserted normal to the flume wall, through and into the H_a stilling well. The center of this tube should be about 1½ inches above the floor line. If the water supply to be measured carries a large amount of suspended matter, a second tube may be placed 8 to 12 inches vertically above the lower one. These tubes should be long enough to extend into the stilling well and should be placed carefully so that ends are flush with the inside face of the flume wall. Figure 2 also shows the location of the tube for the throat connection into the H_b stilling well.

Because of the wide top opening of the stilling well, the light is strong enough and the angle of sight most favorable for easy reading of the graduations on the staff gage, and the sloping side wall is an advantage when accumulated deposits have to be removed from the well. It is recommended that the bottom of the well be set about 1 foot below the floor line of the flume to provide a catch basin for the sand and silt entering through the tubes, thus providing protection against clogging the lower inlet tube.

This type of stilling well is also well suited to the operation of an ordinary water-stage recording instrument. If a water-stage recorder is used, the well should be made about 2 feet wide to allow sufficient room for the float and counterweight. An 8-foot Parshall measuring flume with a water-stage recording instrument set over the stilling well is shown on the cover of this bulletin. The ordinary single-stage recorder is adapted to free-flow conditions only. Where the flow is submerged, a special double head recorder is necessary; the H_a and H_b stilling wells may be combined in a single well having a watertight partition or diaphragm with suitable pipes leading to the proper inlet points in the flume. The arrangement of stilling wells shown in figure 10 is suitable for the operation of a double-head recorder.

VELOCITY OF APPROACH, WEIRS AND FLUME

For some types of measuring devices, such as the weir, it is known that when the stream of water approaches the section of measurement at a greater rate of speed than the standard or correct velocity, the actual discharge will be greater than the indicated discharge. This difference is not great for moderate velocities of approach, but if the rate is greatly increased, a very marked effect upon the discharge will result.

The velocity of approach, in the case of the weir, is materially affected by deposits of sand and silt in the weir pond. These deposits reduce the section through which the water passes and thus increase the velocity of the flow as it approaches the weir notch.

Laboratory tests on a 2-foot Parshall measuring flume show no material effect in the indicated rate of discharge for an H_a head of 1 foot with an increase of 300 percent in the velocity of approach, whereas for a 2-foot rectangular weir with a head of 1 foot and bottom contraction at 1½ feet, it is found that an increase in the velocity of approach of 300 percent results in an actual overregistration of about 7.8 percent.

LOSS OF HEAD, WEIRS AND FLUME

The weir, operated under standard conditions of setting, is the most accurate of the practical measuring devices, but it requires in its operation a relatively large loss of head. Table 7 gives a comparison of the loss of head for the Parshall measuring flume with three types of weirs. The values given under the headings for the various weirs represent the actual heads or depths on the crest required to give corresponding discharges. In reality, the loss of head is greater than that indicated by the difference in elevation between the downstream water surface and the weir crest. This additional fall is necessary to permit the free passage of air underneath the nappe, or overpouring stream of water, and may be assumed to be from 0.05 to 0.1 foot. This comparison indicates that the loss of head required in the use of weirs is approximately four times as great as that needed for the Parshall flume where the crest length of weir and flume are the same and the flow through the flume is submerged to the free-flow limit.

TABLE 7.—*Comparison of loss of head in feet for equal discharges through a Parshall measuring flume and over weirs*

Discharge	Loss of head through Parshall measuring flume				Loss of head over rectangular weir				Loss of head over Cipolletti weir				Loss of head over 90° triangular notch weir
	6-inch	1-foot	2-foot	4-foot	6-inch	1-foot	2-foot	4-foot	6-inch	1-foot	2-foot	4-foot	
Sec.-ft.	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
0.10	0.06				0.15				0.15				0.27
.50	.18	0.08			.46	0.29			.43	0.28			.52
1.00	.32	.14	0.09		.74	.46	0.29		.64	.44	0.28		.69
2.00	.55	.22	.14	0.09	1.16	.75	.46	0.29	.96	.69	.45	0.28	.92
3.00		.28	.18	.12		.99	.61	.38		.88	.58	.37	1.08
5.00			.25	.16			.86	.53			.82	.52	1.32
7.50			.33	.21			1.13	.70			1.06	.68	
10.00			.39	.25			1.38	.85			1.27	.83	
12.50				.28				.99				.96	
15.00				.33				1.12				1.08	
20.00				.40				1.36				1.31	

SUMMARY

Experience in the management and distribution of irrigation water indicates definitely the need of accurate and dependable measurements of flow; first, because equitable distribution of the common supplies is essential to harmony; and second, deliveries made in the proper and just amounts curtail waste and promote attentive practice in effecting high irrigation efficiency. Through systematic and careful measurements of delivery the greatest economy can be attained and increased acreages served adequately.

Weirs when maintained under standard conditions measure accurately, but field experience indicates that neglect in maintenance and other limitations shows this type of device to be questionable in its operation. Weirs are unsuited for use in channels having slight grade. Free-flow through the weir requires considerable loss in head or sacrifice in grade of channel.

A widely adaptable means of measuring irrigation supplies at the source and in deliveries to farms, is the Parshall measuring flume.

This measuring device has a number of advantages: It is accurate enough to meet practical needs; has the ability under almost all conditions of operation to cleanse itself of sand and silt which otherwise would cause doubtful measurements; will withstand a relatively high degree of submergence without affecting the indicated free-flow discharge shown by a single head measurement; tolerates a high degree of submergence as a single head measuring device, permitting operation with a relatively small loss of head; is operated readily to measure submerged flows by the use of two observed heads; has a discharge capacity ranging from less than 0.1 second-foot through a 3-inch flume, to more than 2,000 second-feet through a 40-foot flume; cannot be easily altered in dimensions or influenced to produce unfair or erroneous measurement; is constant in its dimensions and setting and therefore dependable in accuracy; may be made of metal, wood, or concrete. The large flumes are usually reinforced-monolithic concrete, but for the small sizes (2 feet and under) metal is often used, as metal flumes are portable and easily adapted to any desired operating conditions.

U. S. GOVERNMENT PRINTING OFFICE: 1942

For sale by the Superintendent of Documents, Washington, D. C. - - - - Price 10 cents